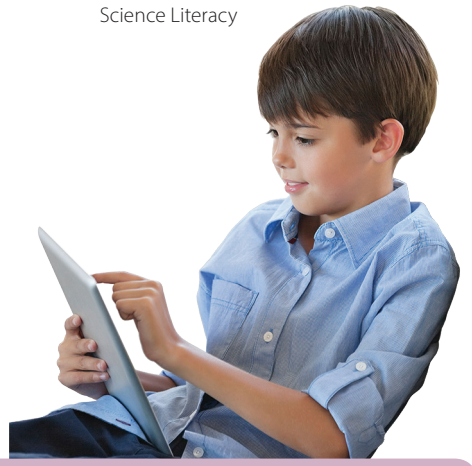
Science Literacy

Earth in Space:

How are we connected to the patterns we see in the sky and space?



Teacher Guide



Skywatching

Lunar eclipse

GRADE 8 Core Knowledge Science®

Core Knowledge®

Earth in Space:

How are we connected to the patterns we see in the sky and space?

Teacher Guide



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BEFORE YOU BEGIN

Before introducing the unit, please become fully acquainted with the program instructional model and classroom routines by reading the online resource **Teacher Handbook: Overview of the Core Knowledge Middle School Science Program**.

Online Resources



Use this link to download the **CKSci Online Resources Guide** for this unit, which includes specific links to:

- the unit's comprehensive materials list
- a full unit pacing snapshot
- lesson guidance slides
- all other recommended resources.

www.coreknowledge.org/cksci-online-resources

Student Work Pages



All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources.

Student Books



All student handouts and exercise pages are included in the consumable Student Work Pages book so that there is no need to print copies of these resources. Students also will use the Student Procedure Guide and the Science Literacy Student Reader throughout the unit.

UNIT OVERVIEW

How are we connected to the patterns we see in the sky and space?

Humans have always been driven by noticing, recording, and understanding patterns and by trying to figure out how we fit within much larger systems. Students begin observing the repeating biannual pattern of the Sun setting perfectly aligned between buildings in New York City along particular streets and then connecting, exploring, and trying to explain additional patterns in the sky that they and others have observed. Students draw on their own experiences and the stories of family or community members to brainstorm a list of patterns in the sky. They listen to a series of podcasts highlighting indigenous astronomies from around the world that emphasize how patterns in the sky set the rhythms for their lives, their communities, and all life on Earth. These are added to their growing list of related phenomena (other patterns in the sky people have observed). In the first two lesson sets, students develop models for the Earth-Sun and Earth-Sun-Moon systems that explain some of the patterns in the sky that they have identified, including seasons, eclipses, and lunar phases. The end of the second lesson set and start of the third lesson set problematizes a predicted observation from the model they developed that they cannot fully explain. This unexpected observation leaves them wondering about why the Moon does not go completely dark during a lunar eclipse and instead turns a dim red color. In the third lesson set, students investigate a series of related phenomena motivated by their questions and ideas for investigations. These include rainbows, sunsets, and other sky and space phenomena related to changes in color and light. In the final lesson set, students explore the remaining questions on their Driving Question Board, related to planets and other objects farther out in space (beyond the stars they can see with the unaided eye). In this lesson set they explore scale and develop a model of the solar system and figure out that gravity is the driving force behind the patterns of motion of these objects and the organization of the solar system as well as the driving force behind the organization of more distant systems (galaxies) that we cannot see with unaided eyes from Earth. Throughout the unit, students will do the following:

- Develop and use both physical and conceptual models of objects in space to explain seasonal temperature variation across the globe, lunar phases, lunar eclipses, solar eclipses, and transits of Venus and Mercury.
- Attend explicitly to the perspective taken by the observer in their systems models and eventually include multiple perspectives at various scales, beginning here on Earth and expanding out to include the solar system and galactic scales.
- Use simulations to look for patterns of objects over time, including carrying out experiments on how the part of the Moon that is visible at a particular part of a lunar month is related to the position of the Moon related to the Earth and a person on Earth and the factors that influence the orbits of one object around another.

- Analyze, interpret, and collect data about objects in the solar system in order to gather evidence to explain the patterns we see in the sky and space with both our unaided eyes and from telescopes and spacecraft, as well as results from a computer simulation of the formation of the solar system.
- Investigate phenomena and develop a model of light that can account for changes in color and brightness when it interacts with matter, and then revise a lunar eclipse model to represent the Earth-Sun-Moon system and that the matter in Earth's atmosphere selectively absorbs and bends light from the Sun to color the Moon red.
- Obtain information about objects in the sky and space that connect to observations made by other cultures and people throughout history.

Focal Disciplinary Core Ideas (DCIs): ESS1.A, ESS1.B, PS2.B, PS4.B

Focal Science and Engineering Practices (SEPs): Developing & Using Models; Analyzing & Interpreting Data; Obtaining, Evaluating, & Communicating Information

Focal Crosscutting Concepts (CCCs): Patterns; Cause & Effect; Scale, Proportion, & Quantity; Systems & Systems Models

Building Toward NGSS Performance Expectations

MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.

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

MS-ESS1-1: Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.

MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

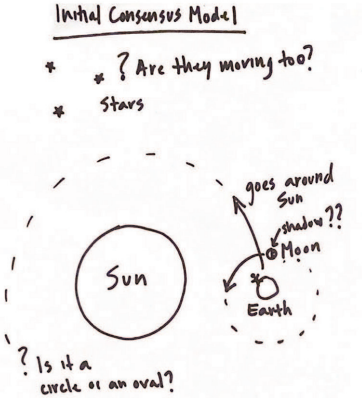
MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.

UNIT STORYLINE

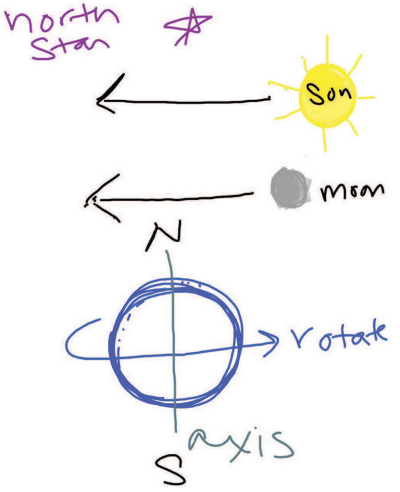
How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES	VIDEOS OR IMAGES	DATA SETS	READINGS	COMPUTER INTERACTIVES

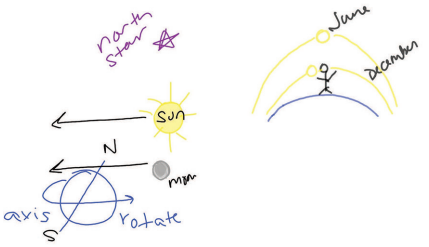
How are we connected to the patterns we see in the sky and space?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 1 **4 days** **How are we connected to the patterns we see in the sky?** Anchoring Phenomenon	 *People across cultures and time have studied the sky and relied on connections to the sky in their lives.*	We analyze and consider how light from the Sun aligned with structures made by humans on a particular day and develop an initial model to explain this phenomenon. We gather, connect with, and jigsaw stories about patterns in the sky they have seen or heard about and how these might be connected to the rhythms of human life. We develop a model of the parts of the system that are needed to explain many of the patterns we have identified. We figure out: • Changing patterns in the sky connect to our lives and set rhythms for life on Earth. • Stories and analogies related to the sky are legitimate ways to preserve knowledge about the stars and planets and aid in observing and decision making. • We observe the light coming from distant objects in the sky. • Light travels in a straight line; it must enter our eye in order for us to see the object it came from. • The Earth spins around, or rotates, on its axis once every day and goes around or orbits the Sun once every year. • In order to better explain and understand a complex system, we may need to view/ visualize it from multiple perspectives.	

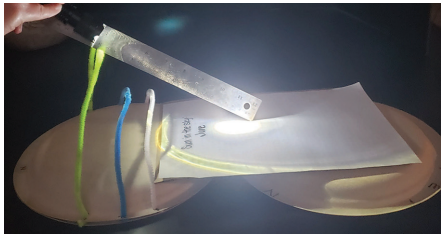
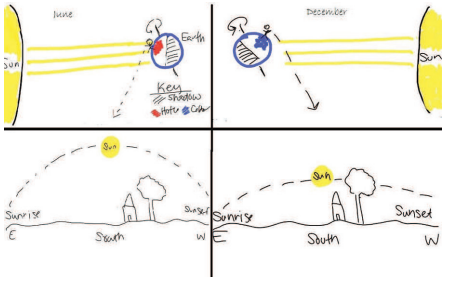
⇩ **Navigation to Next Lesson:** We want to collect more of our own observations of the sky and hear more stories about communities that paid close attention to the sky to see how it shaped their lives.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 2 **1 day** **What patterns are happening in the sky that I have experienced and can observe (through models and tools)?** **Investigation**	 *Patterns of the movement of objects in the sky can be explained by the orientation of Earth's axis.*	We gather information from videos of Native American stories about a star that does not move in the night sky. We share our experiences about noticing this star, sometimes called the North Star. We watch a video and share the repeated patterns and changes that we observe in the sky. We develop initial models to explain why the North Star does not appear to move in the night sky. We figure out: • In the Northern Hemisphere, the Earth's axis is always pointed toward the North Star, which explains why it does not appear to move in the night sky. • The Sun and Moon always appear to rise in the eastern sky, move across the sky from east to west, and set in the west. • The stars visible in the night sky in the Northern Hemisphere appear to move counterclockwise in a circular path around the North Star. This is because the Earth spins counterclockwise on its axis when looking down on it from above its North Pole.	

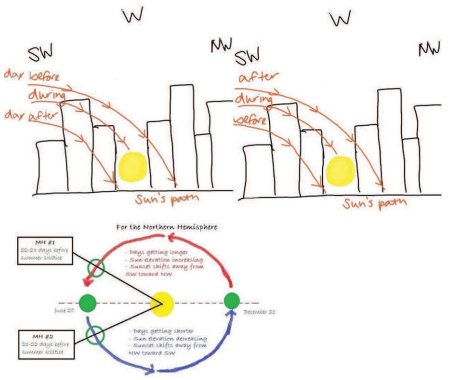
⇩ **Navigation to Next Lesson:** Though we noticed some important patterns of change in the Sun over time, there is something else that remains constant (the Earth's north is always tilted to point toward the North Star). We think there are some possible advantages in trying to develop a model of this system using physical manipulatives to help explain these differences.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 3 **3 days** **How can we explain the Sun's path change over time?** Investigation	 *Patterns of the Sun in the sky and sunlight over the globe vary in predictable patterns every year.*	We watch a video to observe the simulated motion of the Sun through the sky over a day for different times of the year. We notice that in summer the apparent path of the Sun in the sky is higher and the daytime is longer. We create physical models to see if our understanding about why this is happening is correct. Our physical models cannot account for differences in the length of daylight over a year. We revise our model of the system in small groups to try to account for changes in the amount of daylight. We figure out: • Changes in the length of a day and angle of elevation of the Sun in the sky occur in a regular, repetitive, and cyclical pattern. • Earth's axis is tilted at an angle and is pointed in the Northern Hemisphere towards Polaris, also called the North Star. • As the Earth orbits around the Sun and is tilted on its axis, we observe changes in the amount of daylight and how high the Sun is in the sky over the course of the year.	

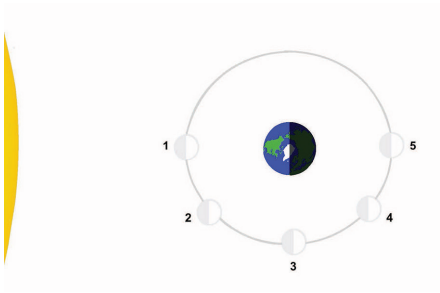
⇩ **Navigation to Next Lesson:** Though we think that what we figured out about what causes the intensity of sunlight on Earth's surface and Sun's elevation in the sky to change over time, we wonder if this could also help explain other seasonal patterns like the change in temperature over the course of a year.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 4 **2 days** **How do these changes in sunlight impact us here on Earth?** Investigation	 *Earth's tilt causes changes in solar elevation which results in seasonal temperature variations.*	We analyze seasonal temperature data from two cities in the US and argue that changes in Earth's distance from the Sun do not explain seasonal temperature differences. We develop a physical model and use it to collect changes of sunlight energy on Earth's surface as a result of changes in solar elevation. We use this relationship to explain seasonal temperature differences in other parts of the world. We figure out: • Solar elevation causes differences in the intensity of light reaching Earth's surface throughout the year. • Higher solar elevation results in more direct sunlight and greater light energy reaching Earth's surface, causing higher temperatures. • Lower solar elevation results in sunlight being more spread out and less light energy reaching Earth's surface, causing lower temperatures. • When sunlight is more direct in the Northern Hemisphere, it is at an angle in the Southern Hemisphere, and vice versa.	

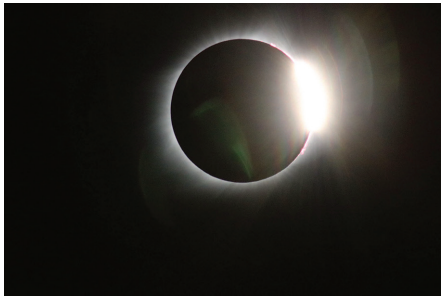
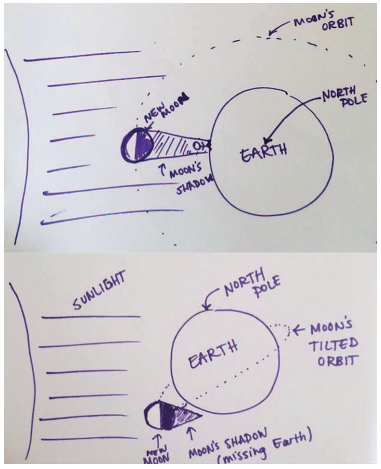
⇩ **Navigation to Next Lesson:** We can use our new understanding about Earth's tilt and solar elevation to revise our models and better explain Manhattanhenge and other related seasonal phenomena.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 5 **1 day** **How can we explain phenomena like Manhattanhenge?** Putting Pieces Together, Problematizing	 *The sun sets between buildings in New York City just two days of the year.*	We use a video simulation to investigate patterns we think might be responsible for Manhattanhenge. We revise a model of the Manhattan solar phenomenon. We revisit the Driving Question Board to connect what questions we have answered and what questions remain. We figure out: • The light rays from the Sun at sunset follow a straight path that happens to align down many streets between the buildings on either side in Manhattan only 2 times a year. • There is a reversal (symmetry) in the pattern of change in where the Sun sets (and rises), the day length, and the angle of the Sun in the sky that occur over the year between the summer and winter solstice. • The fixed tilt of Earth's axis and its orbit around the Sun causes this reversal in these patterns of change between the two extreme points in its orbit, in terms of how much the Earth's tilt is pointed toward the Sun (summer solstice and winter solstice).	

⇩ **Navigation to Next Lesson:** Though we explained a lot about patterns related to the Sun, the Sun wasn't the only thing we were curious about. We also had a lot of questions on the DQB about the Moon. We are wondering how we can add the Moon to our Sun-Earth model to explain some of its patterns.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 **2 days** **Why do we see the shape of the Moon change?** Investigation	 *The shape of the Moon seen from Earth changes monthly from full circle to nothing.*	We use a physical model and an online interactive to help make sense of the positions of the objects in the Earth-Sun-Moon system that cause us to see the current shape of the Moon. We also use our physical models to predict the next phase of the Moon. We figure out: • People have watched the Moon across time and cultures. • Light from the Sun shines on one side of the Moon at any time. The Moon is always "half-lit." • The shape of the Moon we see from one day to the next is a result of its position in space relative to Earth; the appearance of the shape of the Moon that we see on any particular day can be explained in terms of how much of the sunlit side we can see at that time. • We can see the Moon at different times of the day and night—and sometimes not at all.	

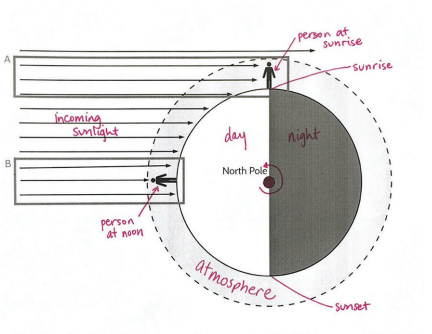
⇩ **Navigation to Next Lesson:** We realized that the Moon can be out during the day and that in certain positions it could affect what we see of the Sun. We now wonder about this phenomenon we think is called an eclipse.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 7 **2 days** **Why do we see eclipses and when do we see them?** Investigation	 *Sometimes the Sun gets blocked by the Moon.*	We watch a video of a solar eclipse. We develop a model to explain what we saw in the video using a physical model of the system. We compile the ideas we want to include in a drawn model using multiple perspectives to communicate what is seen when a solar eclipse happens and why. We return to our physical models to figure out why we do not see a solar eclipse every month and how often we might expect to see a solar eclipse. We figure out the following: • Sometimes the Moon lines up in its orbit between the Sun and the Earth, resulting in the Moon casting a shadow on the Earth. This is what causes a solar eclipse. • The Moon's orbit is not perfectly flat relative to Earth's orbit around the Sun; it is tilted just a little. This is why we don't see eclipses every month.	

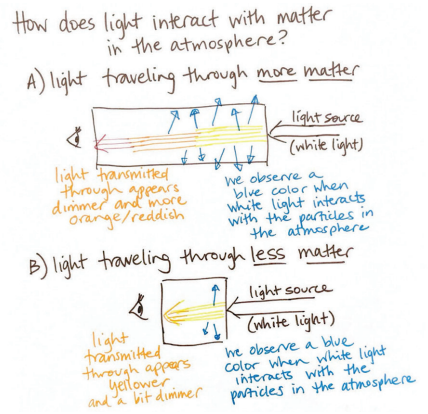
⇩ **Navigation to Next Lesson:** We figured out why and when solar eclipses occur and we predicted what we will see when there is a lunar eclipse. We want to get some additional data on lunar eclipses to see if our prediction was correct.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 8 **1 day** **What does a lunar eclipse look like and how can we explain it?** Problematizing	 *The Moon looks reddish during a total lunar eclipse (not dark like we predicted).*	We analyze images of lunar eclipses and compare them to the lunar eclipse predictive model we made as a class in Lesson 7. The reddish color of the Moon that we observe during a lunar eclipse is unexpected. So we list possible causes of that reddish color and gather examples of related phenomena of objects reddening in the sky. After posting our color-related questions, we generate ideas for investigating them. We figure out: • The Moon is full during a lunar eclipse; this is what our model predicted. • The Moon turns reddish and dim (but is still visible) during a lunar eclipse but does not become completely dark (not visible); this is not what our model predicted. • There are other times when we have experienced the Moon or Sun changing color like this (to reddish or orange).	

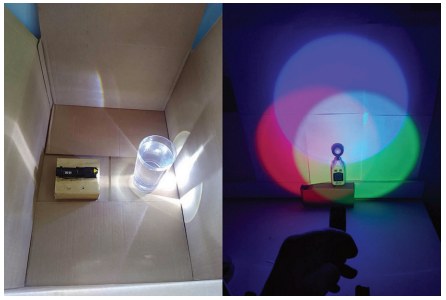
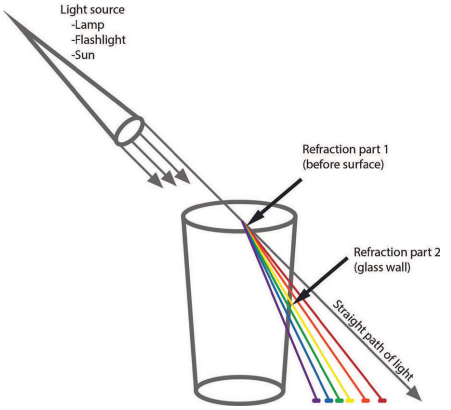
⇩ **Navigation to Next Lesson:** The color change of the Moon in a lunar eclipse (and its dimming rather than completely darkening) was not predicted by our model. So, we plan to explore related phenomena (color and brightness changes of the Sun and Moon at other times) to help us figure out what is happening in the system during a lunar eclipse and help us make progress on other color-related questions.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 9 1 day **Why do the Moon and Sun appear to change color near the horizon?** Investigation	 *The Sun and Moon turn a reddish color when they're rising or setting. Earth is surrounded by an atmosphere that forms a curved layer of gas, water droplets, ice crystals, and dust particles surrounding the entire surface of the Earth, about 60 miles thick, which gets less dense the further up you go.*	We examine images of the Sun and Moon and propose that something about the Earth's atmosphere could be contributing to the color changes. We examine diagrams of the atmosphere and images of the Sun from space. We add the Earth's atmosphere to our model of the Earth–Sun system and zoom in on the Sun at different times. We predict different angles of light and/or the amount of the atmosphere affects the color at sunrise compared to midday. We figure out: • The color (and brightness) of the Moon and Sun change near the horizon. • Sunlight in space is whiter and brighter than sunlight we see from Earth's surface. • Light travels through empty space (even when there is very little or no matter). • The atmosphere looks bluish during the day and from space. • At sunrise and sunset, light from the Sun passes through the atmosphere at a shallow angle; causing the light from the Sun to travel through more of the atmosphere. • Sunlight dims in brightness and appears yellower, oranger, and then redder the more of Earth's atmosphere it passes through.	

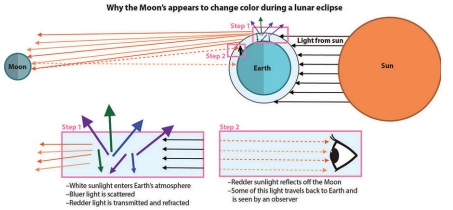
⇩ **Navigation to Next Lesson:** We identified some variables that we think could cause changes in the color of light passing through the atmosphere that we want to investigate further.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 **1 day** **How does light interact with matter in the atmosphere?** Investigation	 *When we shine a white flashlight through narrow and wide clear tubs of water mixed with a little bit of white particulate matter (milk), the color of the light that's scattered off looks bluer than the flashlight color, and the light that transmits through gets oranger or redder the more of that medium it travels through.*	We investigate the color and brightness changes we see as light travels through the Earth's atmosphere by using a flashlight to simulate the Sun and a rectangular bin of milky water to simulate the atmosphere. We use our investigation results to coconstruct a model of light transmitting and scattering through the simulated atmosphere. We figure out: • Although sunlight is white in space, some of the colors are scattered out as it passes through Earth's atmosphere, so it appears yellower, oranger, redder, and dimmer in brightness, the more of Earth's atmosphere it passes through. • When we shine a light through a simulated atmosphere, the white color becomes oranger or redder the more "atmosphere" it travels through and the brightness of the light decreases the longer the path the light travels. • We observe a blue color when white light interacts with particles in the "atmosphere".	

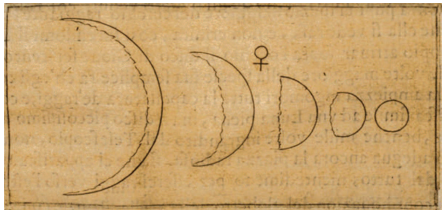
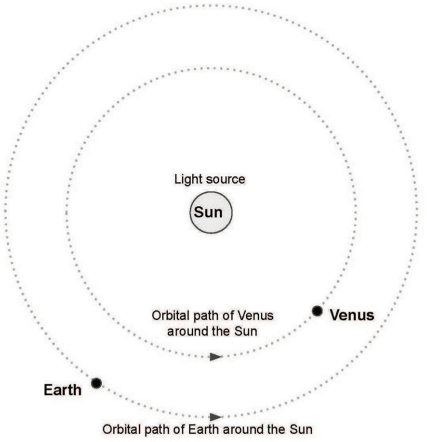
⇩ **Navigation to Next Lesson:** When we shined white light into our simulated atmosphere, the light we saw scattered off the particles was bluish, and the light that was transmitted through was orangish, and the more particles there were, the less light we saw at all. So why are those different colors there after the light interacts with that matter?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 **2 days** **How does the shape of a water droplet or an ice crystal cause sunlight to form into a rainbow?** Investigation	 *Sometimes when light strikes water droplets in the atmosphere, it produces rainbows. The individual colors are less bright than the original light.*	We investigate times, places and perspectives needed to see white light split into its component colors—making a rainbow. We investigate the effect that different materials and their shapes have on (white) light—causing it to change direction (refract) and sometimes make colors and rainbows. We conduct another investigation to recombine colors of light. We discover that combining light in different ways can change the overall color and brightness of the light that you see. We figure out: • Light interacts with water or glass of certain shapes/angles to produce rainbows. • Each color in the rainbow that is produced is less bright than the light that reaches the water/glass; the path that each color of that light follows is a straight line after it leaves the water or the glass. • Materials like water or glass must be able to separate white light into different colors and change their path based on their color. • White light is a combination of colors. • Combining different colors of light together results in more intense light (brighter).	

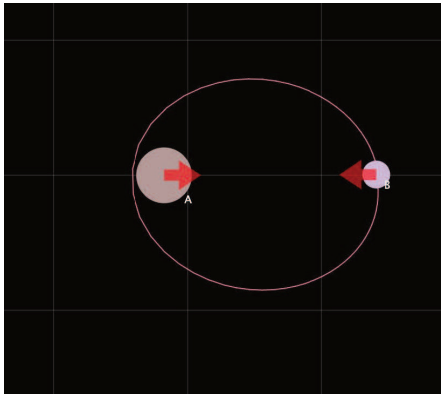
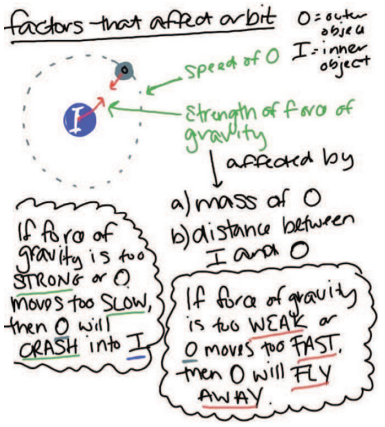
⇩ **Navigation to Next Lesson:** We think our discoveries could help explain why the Moon turns red and not totally dark during a lunar eclipse. We think we can use those ideas to explain other color phenomena.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 12 **2 days** **Why does the Moon always change color during a lunar eclipse?** Putting Pieces Together	 *Objects appear in different colors and in different places under water.*	We celebrate the knowledge we have figured out in previous lessons that can help us explain color change during lunar eclipses. We evaluate models created in those lessons before co-constructing a new model of what is happening during a lunar eclipse. We prepare for and complete a transfer task. We figure out: • Fish lures are used under water where light gets filtered through so they are made in specific colors that transmit better through water at different depths so they will be more visible to the eyes of the fish that are living at those depths than other colors. • Fish appear in different positions under water than they actually are to an observer above the water because the light traveling from the fish to the observer's eye travels out of the water and into the air, bending—or refracting— as it travels from one medium (water) into another medium (air).	

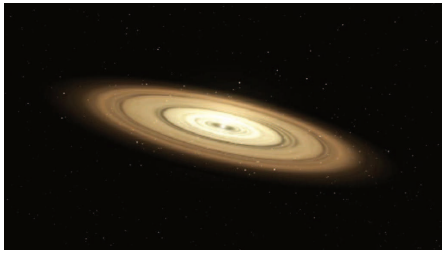
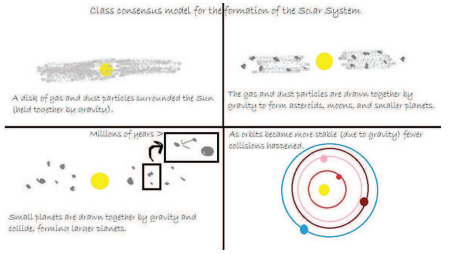
⇩ **Navigation to Next Lesson:** We applied what we figured out to explain other things we see happening under water but still have unanswered questions about patterns of objects we see in the sky and in space.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 13 **3 days** **What new patterns do we see when we look more closely at other objects in the sky?** Investigation	 *Various technologies have been developed over the last 400 years that help us observe changes in the position and appearance of planets in the sky as well as gather additional data from their atmospheres and surfaces.*	We revisit unanswered DQB questions and decide to focus on other objects in our solar system. We gather information from a reading to identify connections and observations about one other planet, Venus. We notice additional patterns in other observations of Venus and record new questions about these. We use a model showing the relative position of motion of Venus and Earth in the system to explain these patterns. We analyze the scale properties of other planets to look for other patterns. We figure out: • Even though Venus and other planets in the sky look like stars, they move differently and their position changes. • Planets closer to the Sun are rocky and small, and those farther out objects are large and gaseous. • All solar system objects orbit the Sun in the same direction (counterclockwise if looking down on Earth's Northern Hemisphere from above it). • There are nested patterns of orbits, but smaller objects tend to orbit larger objects. • Most objects are orbiting the solar system on a similar plane.	

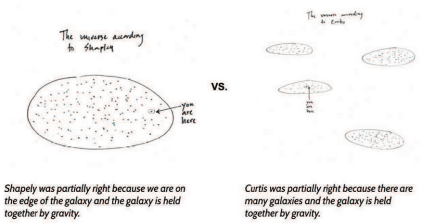
⇩ **Navigation to Next Lesson:** These patterns raise questions about why all of these objects have a steady orbital path and what mechanism(s) can help explain these patterns.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 14 **2 days** **Why do some solar system objects orbit planets and others orbit the Sun?** Investigation	 *A computer interactive allows us to adjust the distance, speed, and mass between two objects and simulate the outcomes from simulated gravitational forces between them.*	We share initial ideas about patterns of motion in the solar system, which leads us to conduct a cause-and-effect thought experiment around those patterns. We use a simulation to investigate how changing distance and size affects an object's orbit around another object in the solar system. We build understanding as a class about the relationship between size, distance, and the strength of the force of gravity before demonstrating our understanding on a formative assessment. We figure out: • Gravity is an attractive force between all matter. • More massive objects have stronger attractive gravitational forces between them than objects that are less massive. • Closer objects have stronger attractive gravitational forces between them than objects farther away. • More circular orbits occur when there is the right combination between the force of gravity and the speed of the orbiting object.	

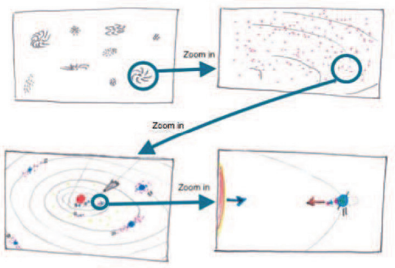
⇩ **Navigation to Next Lesson:** We figured out why objects in our solar system move the way they do now, but wonder if they always moved this way and if they will continue to move this way.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 **1 day** **How did the solar system get to be the way it is today?** Investigation	 *There are many craters visible on moons and planets with little or no atmosphere on them. Simulations that include matter distributed across space in very small particles (dust, molecules, etc.) and gravity force produce outcomes that show how the motion and distribution of that matter changes over time.*	We analyze images of craters on the surface of Mercury and two moons. We watch a video showing the results of a computer simulation that models the formation of the solar system. We develop storyboards to support the claim that the solar system was formed from a disk of gas and dust, drawn together by gravity. We build a class consensus storyboard model of the formation of the solar system. We figure out: • The Sun formed in the center of a disk of gas. • The matter in the disk of gas began to collect to form bigger clumps of matter (e.g., pebbles) due to gravity. • These pebbles collided and clumped together to form smaller planets. • The smaller planets collided many times over several millions of years, resulting in the creation of larger planets, asteroids, and comets. • The collisions became less common as objects in the solar system as the objects had stable orbits.	

⇩ **Navigation to Next Lesson:** Though we made progress on questions on how the structure and motion of the objects in our solar system came to be, we still have questions about what else beyond our solar system. We want to see if telescopes can tell us if there are more patterns and objects in space beyond our solar system and beyond the stars we can see with our unaided eyes.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 16 **1 day** **What patterns and phenomena are beyond our solar system that we cannot see with just our eyes?** Investigation	 *Telescope photos show many distant clusters of stars located in what appears to the unaided eye to be empty space.*	We look at a photo taken by the Hubble telescope of blobs in the space between stars. We learn that these are galaxies, islands of stars much like the ones we see in the sky. We watch the *Tour of the Universe* to visualize how scientists model the universe at various scales. We notice that the universe appears to be organized into systems held together by gravity, separated by vast emptiness. We figure out: • Earth orbits the Sun, making the Sun and Earth part of our solar system along with other planets, asteroids, comets, and so forth. • Moons orbit planets, creating subsystems of the solar system. • Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. • Gravity appears to dictate this organization because in the places where there is stuff, that stuff is held together by gravity.	 *Shapely was partially right because we are on the edge of the galaxy and the galaxy is held together by gravity.* *Curtis was partially right because there are many galaxies and the galaxy is held together by gravity.*

⇩ **Navigation to Next Lesson:** We figured out so much about how systems all over the universe are connected and work, and we want to put this all together and revisit how these patterns these systems produce are connected to our lives in order to close out our Driving Question Board.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 17 **2 days** **How are we connected to all of the systems in space beyond the planet we live on?** Putting Pieces Together	 *From far away, Earth looks like a little pale blue dot floating in space.*	We make a classroom consensus model at various scales to show how gravity organizes the universe. We return to the DQB to take stock of how far we have come in this unit and then reflect on the unit and Earth's place in the universe. We figure out: • We can explain why there is a similar pattern in the motion structure and organization of the largest scale objects and systems in the known universe using the same interactions (gravitational forces that are acting on those objects). • We can answer many of our Driving Question Board questions!	

⇩ **Navigation to Next Lesson:** This is the last lesson in the unit.

LESSONS 1-17

31 days total

Lab Safety Requirements for Science Investigations

It is important to adopt and follow appropriate safety practices within the context of hands-on investigations and demonstration, whether this is in a traditional science laboratory or in the field. In this way, teachers need to be aware of any school or district safety policies, legal safety standards, and better professional practices that are applicable to hands-on science activities being undertaken.

Science safety practices in laboratories or classrooms require engineering controls and personal protective equipment (e.g., wearing safety goggles, nonlatex aprons and gloves, eyewash/shower station, fume hood, and fire extinguishers). Science investigations should always be directly supervised by qualified adults, and safety procedures should be reviewed annually prior to initiating any hands-on activities or demonstration. Prior to each investigation, students should also be reminded specifically of the safety procedures that need to be followed. Each of the lessons within the units includes teacher guidelines for applicable safety procedures for setting up and running an investigation, as well as taking down, disposing of, and storing materials.

Prior to the first science investigation of the year, a safety acknowledgment form for students and parents or guardians should be provided and signed. You can access a model safety acknowledgement form for middle school activities via the **Online Resources Guide**.

Disclaimer: The safety precautions of each activity are based in part on use of the specifically recommended materials and instructions, legal safety standards, and better professional safety practices. Be aware that the selection of alternative materials or procedures for these activities may jeopardize the level of safety and therefore is at the user's own risk.

Please follow these lab safety recommendations for any lesson with an investigation:

1. Wear safety goggles (specifically, indirectly vented chemical splash goggles), a nonlatex apron, and nonlatex gloves during the set-up, hands-on investigation, and take down segments of the activity.
2. Immediately wipe up any spilled water and/or granules on the floor, as this is a slip and fall hazard.
3. Follow your *Teacher Guide* for instructions on disposing of waste materials and/or storage of materials.
4. Secure loose clothing, remove loose jewelry, wear closed-toe shoes, and tie back long hair.
5. Wash your hands with soap and water immediately after completing this activity.
6. Never eat any food items used in a lab activity.
7. Never taste any substance or chemical in the lab.



Specific safety precautions are called out within the lesson using this icon and a callout box.

What is the anchoring phenomenon, and why was it chosen?

The anchoring phenomenon for each unit is chosen from a group of phenomena aligned with the target performance expectations based on student interest survey data and consultation with external advisory panels that include teachers, subject matter experts, and state science administrators. This unit is launched by a phenomenon known as Manhattanhenge. Students analyze how the Sun aligns with the Manhattan skyline one day each year and develop an initial model to explain this engaging and puzzling phenomenon. Although Manhattanhenge is specific to New York City, alignment of the Sun with various human-made structures is a universal experience, and there is guidance in the teacher guide on how to localize for your context. Solar alignment happens every year and is something students can see themselves, whether in a highly urban setting or a local context. Several locations across the country have locally famous solar alignments, such as Chicagohenge (on the Chicago skyline) and Scrippshenge (through a pier in California), but students can also observe solar alignments between pieces of playground equipment or over a school building. People have tracked this phenomena across cultures, and throughout human history, planning construction to align with the Sun on solstices, for example, Carhenge in Nebraska (built in 1987) or the layout of the Cahokia Mounds in Southern Illinois (built sometime around 1100). Students use these patterns to begin making connections between the position of the sunset on Earth, connect it to our daily lives, and brainstorm other interesting patterns that link our lives to the sky. Students also bring in stories from family or community members about patterns in the sky they have seen or heard about and discuss how these might be connected to the rhythms of human life. In a classroom jigsaw, students explore a series of podcasts to learn about ways that humans across cultures and throughout time have relied on and made connections to the sky, and students listen for additional patterns that the astronomers in the podcasts identify. By broadening the set of prior experiences, we can expand the anchor of the unit to build upon the knowledge of students, their families, and the Indigenous communities shared in the podcasts. Students are now personally connected not just to a single phenomena but also to the shared experiences of their peers and all of humanity, and they are able to access more patterns than they may be able to observe directly in the sky where they live. While the anchoring phenomenon for this unit is Manhattanhenge, students expand quickly from this event, and their questions cover a range of celestial patterns that are meaningful to humans and that can all be explained by the deceptively simple mechanics of our solar system.

Supporting students in seeing why the patterns in the sky are relevant to their lives, their communities, and life on Earth

This unit is anchored by stories across culture, space, and time that describe how patterns in the sky have set the rhythms of life on Earth. We begin the unit by considering what causes the Sun to appear directly between two buildings on certain days every year. Support is provided for how to highlight local manifestations of this phenomenon. Students consider how Manhattanhenge is one of many changing patterns in the sky, and they brainstorm other patterns that they have experienced or heard about. Expanding outward from their own experience, students draw on family and community funds of knowledge to bring in stories about patterns they have seen or heard about in the sky and how these might be connected to the rhythms of life on Earth. Framing students' families and communities as legitimate funds of knowledge serves multiple purposes. It (1) helps students feel like they belong in the science classroom by situating their family and community knowledge as productive resources for science; (2) engages students' families in conversations about what is happening in their science classroom; and (3) helps students make connections between the science classroom and their everyday lives.

Expanding outward from our local community, students obtain information from a series of podcasts to learn about ways that humans across cultures and throughout time have relied on and made connections to the sky. Support is provided for how to help students make connections and build on their own cultural resources in processing these podcasts. These podcasts represent just a tiny glimpse into some of the ways that patterns in the sky have set the rhythms for human life across time and space. This is an opportunity to localize this phenomenon for students. Consider inviting a local expert (or several) to come in and give a live interview to the class as an additional point of data. Ask students if they know anyone in their family or community who might be interested. Consider reaching out to local astronomy clubs, universities, community leaders, and/or Indigenous elders. The goal is to help students make connections about why humans study the sky and build on their own multicultural resources to process the information in the podcasts. If you go this route, have students prepare a list of questions beforehand and make a plan for how to distribute among students the work of asking the questions. Consider recording the interview and making the file available online as a "podcast" that the class can share with friends and family. One resource that could support this is available in the **Online Resources Guide**. Throughout the unit, there are opportunities to link back to these podcasts and to cultural knowledge about astronomy. An additional resource about Indigenous sky knowledge can be found online. (See the **Online Resources Guide** for a link to this item.)

These podcasts were chosen to begin this unit for a variety of reasons.

- **Motivation:** Understanding how humans across time and space have articulated the relationships between our lives and the sky can help students form connections about why the content matters to them.
- **Understanding:** Considering more than one perspective on a phenomenon makes our understanding of that phenomenon more robust.
- **Identity:** Highlighting more than one legitimate cultural way of knowing helps students from all backgrounds see an identity for themselves in science.

Please present these podcasts to students not as stories about ancient or outdated ways of thinking about the world but as legitimate, living bodies of knowledge. This knowledge is not lesser than but rather a complement to Western scientific ways of knowing. Humans have always been driven by noticing, recording, and understanding patterns and by understanding our perspective and belonging within a larger system. In addition, whenever we consider cultural identity in the classroom, it is important to avoid framing this identity as static and homogenous instead of recognizing that all people have multilayered and multicultural identities. It can be easy to tokenize cultural stories. The goal is to respect but not oversimplify differences.

What are the NGSS Dimensions developed in this context?

Disciplinary Core Ideas are reproduced verbatim from *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, National Research Council, Division of Behavioral and Social Sciences and Education, Board on Science Education, Committee on a Conceptual Framework for New K-12 Science Education Standards, National Academies Press, Washington, DC. This material may be reproduced and used by other parties with this attribution. If the original material is altered in any way, the attribution must state that the material is adapted from the original.

In the **first two lesson sets** (Lessons 1–5 and 6–7), students develop models for the Earth-Sun and Earth-Sun-Moon systems that explain some of the patterns in the sky that they have identified after working with a set of podcasts highlighting Indigenous astronomies from around the world in Lesson 1. In Lesson 3, students engage first with a physical model and refine it to explain how the patterns of the Sun they see in the sky change throughout the day and year. They then begin to come to consensus around a visual language for modeling these systems on paper to explain specific patterns. These diagrams attend explicitly to the perspective taken by the observer within the system The use of multiple perspectives at various scales in systems models will be leveraged in subsequent lesson sets. These lesson sets build toward the following performance expectation: ***MS-ESS1-1****: Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.* By the end of the first lesson set, students will be able to explain what causes the patterns in seasonal temperature variation across the globe, lunar phases, and solar eclipses using a model of the motion of some objects in space (the Earth and Moon). But they will not yet have figured out the how and why these objects are organized or move in the sky the way they do. This will come in the fourth lesson set.

In the **third lesson set** (Lessons 8–12), students attempt to make sense of why the Moon appears reddish during a lunar eclipse and does not go completely dark. This leads to additional questions about changes in the color and light of the Sun and Moon at different points in time, which initially emerged in the first lesson set. Students investigate phenomena that necessitate developing a model of light that can account for changes in color and brightness when light interacts with matter. By exploring related phenomena they suggested, such as how do rainbows have different colors and and when do they appear, why are sunsets not all the same color, why is the Sun is a different color at sunset than earlier in the day, and other sky and space phenomena, students build toward a more complete understanding of the science ideas in **MS-PS4-2** (which they began to develop in *Unit 6.1: Why do we sometimes see different things when looking at the same object?* [*One-way Mirror Unit*]): *Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.* These investigations are motivated by a set of patterns identified by students related to puzzling but common color changes in the sky, like a blood Moon during an eclipse, a rainbow after a storm, or a red sunset on a smoky day.

In the **fourth and final lesson set** (Lessons 13–17), students shift to exploring larger-scale systems such as the solar system, galaxies, and the universe that help them build toward the following performance expectation: ***MS-ESS1-3****: Analyze and interpret data to determine scale properties of objects in the solar system.* Students will be moving from patterns in the sky that have been observed and recorded for thousands of years of human history to using data from tools such as telescopes and space probes. These investigations begin by students making observations of the changing appearance, location, and movement of Venus over time and noting that these patterns are different from that of the Moon and Sun (or other stars) in the sky. Students expand their model of the system to explain these observations, as well as observations of Mercury, Mars, and Jupiter, to include some orbital paths around the Sun that are inside the Earth's and some that are outside of it. After identifying patterns in the scale properties of other planets in the solar system, students figure out that gravitational interactions are the driving force behind the orbital motions

of these objects. They use simulations to model and understand the factors that affect gravitational forces and the orbits of objects in space and the formation of the solar system. In addition, students figure out that gravity shapes larger space systems like galaxies by shaping the orbits of stars around a central mass. At the end of this lesson set, students begin to consider how gravity dictates the organization of all of these systems in space and how we can create representations at multiple scales to include multiple systems to model the patterns we see in the solar system and beyond. This lesson set builds toward the following performance expectations: ***MS-ESS1-2****: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system* and ***MS-PS2-4****: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects*. By the end of the second lesson set, students have the tools they need to draw connections across MS-ESS1-1, MS-PS2-4, and MS-ESS1-2 and describe how many of the patterns we see in the sky can be explained using models of space systems and subsystems at various scales and how the motions in those systems are all determined by gravity.

This 7-week unit builds toward the following NGSS Performance Expectations (PEs):
MS-ESS1-1: Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons.
MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.
MS-PS2-4: Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects.
MS-ESS1-3: Analyze and interpret data to determine scale properties of objects in the solar system.
MS-PS4-2*: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
*This performance expectation is developed across multiple units. This unit reinforces or works toward these NGSS PEs that students should have previously developed or will develop more fully in future units. In the OpenSciEd Scope and Sequence, PS4-2 is first built in *One-way Mirror Unit*.

Focal DCIs	Focal Science and Engineering Practices	Focal Crosscutting Concepts
ESS1.A: The Universe and Its Stars Patterns of the apparent motion of the Sun, the Moon, and stars in the sky can be observed, described, predicted, and explained with models. **(MS-ESS1-1)** Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. **(MS-ESS1-2)** **ESS1.B: Earth and the Solar System** 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. **(MS-ESS1-2) (MS-ESS1-3)** This model of the solar system can explain eclipses of the Sun and the Moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the Sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. **(MS-ESS1-1)** The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. **(MS-ESS1-2)** **PS2.B: Types of Interactions** Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the Sun. **(MS-PS2-4)** **PS4.B: Electromagnetic Radiation** A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. **(MSPS4-2)** However, because light can travel through space, it cannot be a matter wave, like sound or water waves. **(MS-PS4-2)**	**Developing and Using Models:** Students develop, use, and revise models beginning in Lesson 1 and throughout the unit to explain patterns in the sky ranging from why Manhattahenge occurs twice a year in the same spot, why the seasons in Australia are opposite of seasons in the Northern Hemisphere, why the Moon appears redder during a lunar eclipse but does not go completely dark, why planets go around the Sun and moons go around planets, our place in the solar system and galaxy, and more. **Analyzing and Interpreting Data:** Students use multiple graphical displays (e.g., maps, scatter plots) of large data sets to identify and explain patterns in sky (such as solar elevation, length of day, location and paths of motion for objects in the sky, and the organization of the solar system. **Obtaining, Evaluating, and Communicating Information:** Throughout the unit students are gathering, reading, synthesizing and information from multiple sources (e.g., text, data, maps, graphs, images). This is an 8th grade unit toward the end of the year, so students have already had much experience in this practice so while students are given several close reading or listening protocols, some of the scaffolding has been removed from previous units so they can execute the practice on their own.	**Patterns:** From the start of Lesson 1, students are noticing patterns in the sky and return several times throughout the unit with their community guide to make note of more patterns they and others feel connected to and observe in the sky. This is built out in Lessons 2 and 3 as they begin to notice repeating patterns not just over days but thousands of years, throughout the unit, and that those patterns can be expanded to systems at great scale such as the organization of the solar system and galaxies due to gravitational forces. **Scale, Proportion, and Quantity;** Students will gradually build out to the vast scale of the universe starting in Lesson 1 by modeling Manhattanhenge, which just involves a two-object system at one scale, to chose another pattern they feel connected to in order to model from different perspectives, and working toward a model with multiple scales between them in Lesson 17, including galaxies, stars, and additional objects/subsystems in the solar system. **Systems and System Models:** Integrated in the Lesson 1 initial models to explain a pattern in the sky chosen by each student is students beginning to make sense of the parts and interactions in the system to explain the causality of their model. Models throughout the unit link components about the motion, positions, and appearance of objects within their subsystems and placement within larger systems. By Lesson 17, students can model each individual subsystem zooming in on the parts and interactions from a galactic scale all the way down to a two-object system, such as the Earth-Moon or Earth-Sun systems. The unit also includes opportunities to practice using Cause and Effect, Stability and Change, and Structure and Function.

Using patterns, systems, and scale to organize student sensemaking in this unit

The unit uses crosscutting concepts to help students organize and make sense of the patterns they identify in the anchor and throughout the unit. The focal crosscutting concepts for the unit—patterns; systems and systems models; and scale, proportion, and quantity—are not unique to Western science. Humans have always been driven by noticing, recording, and understanding patterns and by understanding how we belong within a much larger system. Building telescopes and spectrometers to gather data is just one of the ways that humans have responded to that drive.

Patterns

If your students have just finished Unit 8.3 (Magnets), they have been thinking about the world in terms of cause and effect. Explicitly make the connection here between cause and effect and the patterns in the sky students are investigating in this unit. Consider engaging students in making these connections by asking, *How do cause-and-effect relationships relate to patterns? How could you use the cause-and-effect sentence frames that we used to explore the speaker to talk about patterns in the sky?* Students might suggest (or you might introduce) a modified sentence frame such as this:

When *something in space happens*, we will observe *this pattern*.

Systems and Systems Modeling

If you haven't taught systems before, you may need to provide additional scaffolding for students. Consider using *Systems Modeling Scaffold* to lead a discussion about systems. You can have students discuss the questions on the handout to establish an understanding of systems models. The goal is for students to get more comfortable with figuring out which parts of the system need to be included in the model versus which parts are irrelevant and get a sense of what it means for those parts to interact.

To scaffold the idea of perspective, you might also consider asking students to imagine what the system might look like from another point of view, for example, that of the bird or that of the person on the surface of the Earth.

The terms *parts* and *components* are used interchangeably in the NGSS and in OpenSciEd. Using both words can be confusing for students, particularly emergent multilinguals, so be explicit when you use a synonym. Now might be a nice time to remind students that *parts* and *components* are different ways to refer to the things in a system that work together, but they can be used interchangeably.

In Lessons 1–7 students identify parts, motions, and interactions when looking at the Earth-Sun-Moon systems. In Lesson 13, they notice several patterns in the organization of the solar system such as rocky planets close to the Sun and larger gas planets farther away, moons go around planets that go around the Sun, and the farther away the planet the longer it takes to go around the Sun. This leads them in Lesson 14 to notice that all the movements in the system can be explained by gravity forces, and thus these movements are indications of an interaction. From that point on, they identify only parts and interactions. By Lesson 16, students have determined how gravity forces cause the patterns of motion and organization of objects in space systems, at multiple scales ranging from the Earth-Moon system all the way out to galactic systems.

Scale, Proportion, and Quantity

The crosscutting concept of Scale, Proportion, and Quantity is central to this unit and to understanding space systems. According to the NGSS, "Before an analysis of function or process can be made (the *how or why*), it is necessary to identify the *what*. These concepts are the starting point for scientific understanding, whether it is of a total system or its individual components. An understanding of scale involves not only understanding that systems and processes vary in size, time span, and energy, but also that different mechanisms operate at different scales" (NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press. Appendix G, p. 418).

In middle school, students are expected to understand that some phenomena can be observed at various scales using models to study systems that are too large, like space phenomena. Because our perspective on Earth is limited, phenomena that can be observed at one scale, for example, by simulating the whole solar system at once from a perspective above the system, may not be observable from our perspective. Many of the familiar patterns we see on Earth are a symptom of this limitation of perspective and our inability to observe the system at scale.

How is the unit structured?

The unit is organized into four lesson sets. Lessons 1–5 focus on developing science ideas about the Earth-Sun system. In Lessons 6–7, students add the Moon into the system and are left wondering why lunar eclipses do not go completely dark. This leads them to investigate more phenomena related to color and light in lessons 8–12, in order to explain the redder color of the Moon during lunar eclipses. In Lesson 13, students note that their questions can no longer be answered just by observations from Earth and their unaided eyes, which motivates them to use tools to see better and farther into space, expanding the scale of their models. This drives them to wonder about why

the solar system is organized the way it is and how it got to be that way, which motivates them to investigate how gravitational interactions dictate the organization and motion of objects within each system and how this holds true for multiple scales and subsystems in the final lesson set, Lessons 13–17.

Driving question: How are we connected to the patterns we see in the sky and space?

Lesson Set 1 : How can we explain the patterns of the Sun we see and connect to in the sky and space?

Lesson 1

Students analyze how the sunset has aligned with human-made structures and consider other interesting patterns in the sky from their own experiences, community members' ideas, and additional cultures' stories about how these patterns are connected to the rhythms of human life.

Lessons 2-4

Students investigate patterns they and others have observed in the sky related to the Sun and stars, then analyze seasonal temperature data and to explain seasonal temperature variation and determine why the seasons are opposite in Australia from the United States.

Lesson 5

Students use what they have figured out about the Earth and Sun system to model and explain the sunset alignment phenomena from Lesson 1.

Lesson Set 2: How can we explain the patterns of the Moon we see and connect to in the sky and space?

Lessons 6-7

Students investigate patterns they and others have noticed in the shape of the moon over time for lunar phases and eclipses and develop a physical model of the earth, sun, moon system to explain and predict these patterns.

Lesson Set 3: Why do we see colors change in the sky and space?

Lesson 8

Students analyze images of lunar eclipses, list possible causes for the unexpected changes in color and dimness in its appearance. They brainstorm other color related phenomena for object and add additional color-related questions and ideas for investigations.

Lessons 9-12

Students investigate what happens to the color, brightness, and bending of light as it moves from its source to their eyes (or other detectors) and then apply what they have figured out to lunar eclipses and to a new phenomenon: light changes underwater.

Lesson Set 4: How can gravitational forces explain the patterns in the organization of the Solar System, galaxies, and the universe?

Lesson 13

Students investigate patterns of objects beyond the Earth, Sun, and Moon because many of their unanswered questions pertain to patterns in objects and the motion of those objects in the sky and space.

Lessons 14-16

Students want to know why objects in space move the way they do, so they investigate the gravitational forces influencing the movement of those objects and the formation of the Solar System.

Lessons 16-17

Students zoom out to a galactic scale and then back down to the Earth-Moon-Sun System to make connections between the systems of the universe at different scales with regards to gravity.

Where does this unit fall within the Scope and Sequence?

This unit is the fourth 8th grade unit and designed to be taught just after *Magnets Unit* in the Scope and Sequence. As such, it can leverage ideas about distance forces and field-based thinking, which is especially helpful where in the space above the Earth and Moon and between them gravitational forces would be found, which lays the groundwork for even larger scale system organization and motion due to gravity.

Additionally, another prior unit, *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, can provide science ideas for students as they they investigate the effect of changes in the atmosphere (or even any atmosphere versus no atmosphere) on the apparent color of the Moon during a lunar eclipse or other phenomena in the sky, such as rainbows and sun dogs.

What additional ideas will my students have or know from earlier grades or units?

This unit introduces students to the mechanisms behind many of the common patterns they have noticed in grades K-5. For example, students finish elementary school having figured out that patterns of the motion of the Sun, Moon, and stars in the sky can be observed, described, and predicted. But they have not shifted their perspective beyond Earth-bound patterns to examine the space systems that explain these patterns, nor have they had the chance to explore the rich cultural connections between celestial patterns and human life. In this unit, we begin where students left off in elementary, capturing as many of these patterns and experiences as possible on our Driving Question Board. We then move quickly beyond describing to explain how enormous celestial spheres falling toward one another in space can create the remarkable predictability of celestial motions that we observe here on the surface of our own sphere—Earth. This conceptual shift in perspectives and scale, from our planet's surface, to the nested space systems that surround us , is what marks the change from elementary ideas, to middle school models.

This unit uses and builds upon science ideas that students should have previously developed in units *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*, *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)*, *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*, *Unit 8.2: How can a sound make something move? (Sound Unit)*, and *Unit 6.3:*

Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit). From the beginning of the unit, student questions emerge and spiral through the rest of the unit, beckoning learners to explain changing colors and patterns of light in the sky. This motivates them to want to explain how light interacts with the changing position of objects in the Earth-Sun-Moon system to make the Moon appear redder in the sky. Students build off of prior work from the *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* unit to more fully build out the reflection, absorption, and transmission of light through the atmosphere and water. In Lesson 1, students build on earlier work to identify that light/light rays travel in straight lines from a source (in this case, the Sun). For example, in Lesson 2, to develop a physical model to collect and analyze data on how the intensity of the energy from sunlight changes when it hits the Earth at different angles, students revisit MS-PS4-2 and add the frequency (color) of the light.

- A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. **(MS-PS4-1)**
- When light shines on an object, it is reflected, absorbed, or transmitted through the object. **(MS-PS4-2)**
- A sound wave needs a medium through which it is transmitted. (**MS-PS4.A**)
- A sound wave transfers energy through air. **(MS-PS4-1)**
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object. **(MS-PS3.C)**
- For any pair of interacting objects, the force exerted by the first object on the second object is equal in strength to the force that the second object exerts on the first, but in the opposite direction. **(MS-PS2.A)**
- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. **(MS-PS4-2)**

What are some common ideas that students might have?

Students will come into the unit with many ideas about the universe derived from previous classroom experiences, intuitive understandings of the way the world works, everyday experiences with movement, and the conversations they have had with parents, friends, and family members. Some relevant ideas that students may come into the unit with include the following:

1. The Sun and Moon orbit Earth.
2. Seasons are caused by Earth's proximity to the Sun.
3. Seasons are caused by the tilt of Earth because parts of the globe are tilted closer to the Sun while the other parts are tilted slightly further away.
4. The Moon is only visible at nighttime.
5. There is a "dark side" of the Moon that causes lunar phases.
6. Lunar phases are caused by the shadow of Earth falling on the Moon.
7. Eclipses are random and cannot be predicted.
8. Stars are scattered within our solar system.
9. Our solar system encompasses the entire universe.
10. Moons are always smaller than planets.
11. We can take photos of other stars with telescopes that will allow us to see planets and surface features.
12. We can take photos of our galaxy by sending spacecraft to above its disk.
13. Light travels instantaneously.
14. Lenses bend light in curved paths.
15. Gravity is caused by Earth's magnetic core.
16. There is no gravity in space, nor on other moons or planets.
17. Gravity is caused by Earth's atmosphere.

It is valuable to think of ideas like these not as misconceptions that need to be erased but as productive ideas that we can use to build understanding. Not only does this help some students feel more comfortable talking about science and build a scientific identity, it improves science learning across the board. For example, in Lesson 2 we are expecting that some students will suggest that the Sun is closer to Earth in summer, causing the temperature variation we see (see relevant idea 2 above). Regardless of if the idea is wrong or right, this is a well-informed idea based on our ideas about energy transfer from previous units and from experience (we feel warmer when we get closer to a heat source). Students who put forward this theory are transferring content knowledge and exercising scientific reasoning in a productive way. Simply telling students that the seasons are caused by the tilt of Earth, its curvature, and its orbit around the Sun is not as productive as investigating the inaccurate theory and building evidence against it that will help students construct a new, more accurate conceptual model for space systems.

How will I need to modify the unit if taught out of sequence?

This is the fourth unit in 8th grade in the Scope and Sequence. Given this placement, several modifications would need to be made if teaching this unit earlier or later in the middle school curriculum. These include the following adjustments:

- If taught before *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* or *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, supplemental teaching of the definitions of *forces* would be required to help students model what causes gravitational forces, why they vary, and why they can produce relatively stable orbits in some conditions. These ideas are leveraged in Lesson 13 and beyond in this unit.
  - From *Unit 8.1: Why do things sometimes get damaged when they hit each other? (Collisions Unit)* or *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*: Force pairs are the result of the interaction of two objects or systems. There are no single forces. Each force in a force pair is equal in strength, opposite in direction, and acting on a different part of the system or object in the system.
  - From *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*: Some forces act a distance rather than through contact between matter. Magnetic fields can be used to map and visualize the direction and strength of magnetic forces at various distances from one or more objects in a system. Distance affects the strength of these forces.
- If taught before Unit 8.1 (or at the start of the school year), supplemental teaching of classroom norms, setting up the Driving Question Board, and asking open-ended and testable questions would need to be added. (These supports are built into 8.1.)

How do I shorten or condense the unit if needed? How can I extend the unit if needed?

The following are example options to shorten or condense parts of the unit without eliminating important sensemaking for students:

- **If your context dictates shorter amounts of time for a unit or you need to break the unit up into smaller parts:** Chunk the unit into Lessons 1–5 (Lesson Set 1), 6–7 (Lesson Set 2), 8–12 (Lesson Set 3), and 13–17 (Lesson Set 4). Lesson Sets 1 and 2 should be taught in sequence and before Lesson Set 4, but Lesson Set 3 could be skipped if you do not need to address MS PS4-2, or it could be moved to be taught after Lesson Set 4. If you do the latter, you would need to adapt the navigation into Lesson 8.
- **Lesson Set 3:** If students do not have questions about color and light or your state or district does not require that Physical Science Performance Expectations be a part of this unit then you can skip Lesson Set 3 (Lessons 8–12).
- **Lesson 4:** If students don't have as many questions about deep space interactions, you may want to trim some of the lessons from **Lesson Set 4** (Lesson 13–17).

To extend or enhance the unit, consider the following:

- **Many lessons:** Within many lessons are extension readings, videos, simulations, or activities offered as alternates or home learning. If you find that students are highly engaged or looking for a challenge, offer these readings as either in-class or home learning extensions.
- **All lessons:** Remove scaffolds provided with Science and Engineering Practices as a way to give students more independent work with the elements of these practices.

What mathematics is required to fully access the unit's learning experiences?

This unit is not math intensive. Prerequisite math concepts from students' math classes include the following:

- CCSS.MATH.CONTENT.7.RP.A.1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas, and other quantities measured in like or different units.
- CCSS.MATH.CONTENT.7.RP.A.1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas, and other quantities measured in like or different units.

What additional strategies are available to support equitable science learning in this unit?

Units are designed to promote equitable access to high-quality science learning experiences for all students. Each unit includes strategies that are integrated throughout the routines and are intended to increase relevance and provide access to science learning for all students. Units support these

equity goals through several specific strategies such as: (1) integrating Universal Design for Learning (UDL) Principles during the unit design process to reduce potential barriers and provide more accessible ways in which students can engage in learning experiences; (2) developing and supporting classroom norms that provide a safe learning culture; (3) supporting classroom discourse to promote students in developing, sharing, and revising their ideas; and (4) specific strategies to supporting emerging multilingual students in science classrooms.

Many of these strategies are discussed in the teacher guides in sidebar callout boxes titled "Attending to Equity" and subheadings such as "Supporting Emerging Multilingual Learners" or "Supporting Universal Design for Learning." Other callout boxes with strategies are found as "Additional Guidance", "Alternate Activity," and "Key Ideas" and various discussion callouts. Finally, each unit includes the development of a Word Wall as part of students' routines to "earning" or "encountering" scientific language.

For more information about each of these different strategies with example artifacts, please see the Teacher Handbook.

GUIDANCE FOR DEVELOPING YOUR WORD WALL

This unit refers to two categories of academic language (i.e., vocabulary). Most often in this unit, students will have experiences with and discussions about science ideas before they know the specific vocabulary word that names that idea. After students have developed a deep understanding of a science idea through these experiences, and sometimes because they are looking for a more efficient way to express that idea, they have "earned" that word and can add the specific term to the class Word Wall. These "words we earn" should be recorded on the Word Wall using the students' own definition whenever possible. On the other hand, "words we encounter" are "given" to students in the course of a reading, video, or other activity, often with a definition clearly stated in the text. Sometimes, words we encounter are helpful just in that lesson and need not be recorded on the Word Wall. However, if a word we encounter will be frequently referred to throughout the unit, it should be added to the Word Wall. As such, the Word Wall becomes an ongoing collection of words we will continue to use, including all the words we earn in the unit and possibly a few key words we encounter.

It is best for students if you create cards for the Word Wall in the moment, using definitions and pictorial representations that the class develops together as they discuss their experiences in the lesson. When they co-create the posted meaning of the word, students "own" the word—it honors their use of language and connects their specific experiences to the vocabulary of science beyond their classroom. It is especially important for emergent multilingual students to have a reference for this important vocabulary, which includes an accessible definition and visual support.

Sometimes creating Word Wall cards in the moment is a challenge. The teacher guide provides a suggested definition for each term to support you in helping your class develop a student-friendly definition that is also scientifically accurate. If you keep one Word Wall in your classroom for several sections of students, you might choose to record each class's definition separately, and then propose an "official" definition to post the next day that captures the collected meaning.

The words we earn and words we encounter in this unit are listed in this document and in each lesson to help prepare and to avoid introducing a word before students have earned it. They are not intended as a vocabulary list for students to study before a lesson, as that would undermine the authentic and lasting connection students can make with these words when they are allowed to experience them first as ideas they're trying to figure out.

Lesson	Words we earn
L1	pattern, change in perspective
L2	
L3	elevation, Polaris, daily (or diurnally), yearly (or annually), orbit, solar
L4	
L5	
L6	(lunar) phases
L7	eclipse
L8	
L9	
L10	scatter, reflect, transmit
L11	refract
L12	
L13	transit, solar system
L14	gravitational forces
L15	accretion
L16	galaxy, universe

TEACHING SCIENCE LITERACY

How does the Core Knowledge Science Literacy rountine integrate with the unit investigations?

The Core Knowledge Science Literacy Student Reader and the weekly Science Literacy routine layer varied reading opportunities into the science unit. In their lives after graduating from high school, most students will not become scientists. They will no longer routinely participate in guided investigations to figure out how phenomena work. They will, however, read text about science and scientific claims, day in and day out. The ability to learn and think about science through reading is a skill unto itself and is important in tandem with investigative learning. It is natural to primarily associate emerging literacy with reading and writing instruction at the elementary level, but middle school is an important time to hone literacy skills—specifically in science in the era of politicization of science topics, polarization among adults, and proliferation of misinformation on social media. Detection and construction of well-reasoned explanations are important not just in science, but throughout everyday life. Using claims and evidence in reasoning is the way that thoughtful people think about things, and writing is thinking in print. Students become voters as they emerge from high school, so it is important that they acquire skills for detection of faulty information and practice legitimate communication about scientific issues in the years leading up to that civic benchmark.

Throughout the course of the unit's investigative lessons, students write in their science notebooks in some fashion almost daily, and significant emphasis is placed on the speaking and listening communication threads of the CCSS. The instructional design of the investigations is deliberately light on having students access disciplinary core content through text. NGSS emphasis is on students investigating phenomena along the storyline, so students' interaction with text within lessons is minimal and in service to the unit's storyline. The Science Literacy routine is integrated to exercise students' ability to interact with text about science topics. The routine presents students with short reading selections in a variety of styles, all related to the unit in which students are engaged. Each reading selection is accompanied by a brief but thoughtful writing exercise.

The subject matter of the reading selections ties back to the unit, but the timing for the assigned readings is such that students do not read about specific facets of the subject before they have completed the lessons to investigate that content. In other words, the reading enhances and reinforces the knowledge that students have built in previous lessons; the reading does not reveal beforehand the key takeaways that students are intended to learn through lesson interactions.

When is it done within a unit?

The Core Knowledge Science Literacy Student Reader includes one reading collection per week for every week of the unit. A week's reading collection relates to the lessons completed in the previous week. The reading is assigned at the beginning of the week with the accompanying writing exercise due at the end of the week.

The reading and writing exercises are designed to be completed by students independently, with brief, supporting, teacher-facilitated discussions at the beginning, midpoint, and end of the week.

How do students typically represent their thinking as part of the routine?

Students generate a written product associated with each reading selection. The products are varied in form, and include graphic organizers, concept maps, cartoons, memes, infographics, storyboards, outlines, and paragraphs. The complexity of the products increases from week to week, with the final product for the unit being a single, thoughtfully reasoned, and well-constructed paragraph.

Put Yourself in This Scene

Literacy Objective

✓ Initiate thinking about the need to evaluate information in text and images.

Literacy Exercises

- Read a brief scenario to pique interest, launch discussion, and begin to frame expectations.

Instructional Resource



Science Literacy Student Reader, Preface
"Put Yourself in This Scene"

No Prerequisite Investigation

The reading of the Preface is appropriate during the first week of unit instruction. The reading does not preemptively tell students facts about the topic that they are intended to learn throughout the course of their investigations.

Standards and Dimensions

NGSS

Disciplinary Core Idea PS4.B: Electromagnetic Radiation However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2)

Science and Engineering Practice: Asking Questions and Defining Problems

Crosscutting Concepts: Patterns; Connections to Nature of Science

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. No Core Vocabulary terms are highlighted in the Preface.

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

pattern **plausible**

science literacy

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the Science Literacy Student Reader.
- Friday: Set aside time at the end of the week to facilitate a brief discussion about the reading.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know that for the Science Literacy routine, they will read independently and then complete short writing assignments. The reading selections relate to topics they will be exploring in their Earth in Space unit science investigations.
- The reading and writing will typically be completed outside of class (unless you have available class time to allocate).
- The first week's reading is a short introductory segment in the book, and there is no accompanying writing exercise as the unit is getting started.
- The class will discuss the reading together at the end of the week.

SUPPORT—The Preface about the search for intelligent alien life scenario is written at approximately Lexile 1400, which leans toward the high end of the expected text complexity band for middle school. You may wish to introduce a word identification and comprehension convention into your routine to support struggling readers. Hang an envelope near the door with the label, "When we talk about the next reading selection, I could use a little more help understanding the word(s). . . " Encourage students, as they are reading, to jot words, phrases, or sentences that they are unclear about onto small scraps of paper and tuck them into the envelope at any time preceding the discussion of the reading. Whenever you facilitate class discussion about a reading selection, check the envelope first, and layer in added examples and repeat definitions to help students build comprehension and fluency for terms or complex sentences about which they have revealed they are uncertain.

3. Facilitate discussion. (Friday)

Facilitate a brief class discussion about the Science Literacy Student Reader Preface, entitled "Put Yourself in This Scene."

Student Reader



Preface

Pages 2–3 Suggested prompt	Sample student response
How would you summarize the "scene" referred to in the title?	*A classroom conversation motivates a student to learn more about whether UFOs and intelligent alien life are scientifically possible.*

Pages 2–3 Suggested prompts	Sample student responses
If you wanted to learn more about the search for intelligent aliens, what reliable sources could you use?	*Ask an Earth science teacher.* *Read articles in science magazines, newspapers, or websites.* *Ask a reference librarian for reliable sources.* *Read the NASA website.*
What questions do you have about UFOs and alien intelligence that can be investigated by asking an expert or reading scientific information?	*How many star systems are in the universe?* *What percentage of stars have Earth-like planets that might have life similar to ours?* *Have scientists ever captured an alien UFO?* *UFOs are reported all the time. What are people seeing?* *What interests scientists in searching for aliens?*
What other questions do you have about patterns in the sky and space that can be answered with science investigations and research?	*What are those three bright lights I sometimes see in the same part of the sky at dusk?* *How do scientists predict when an eclipse will occur?* *How do the Stonehenge rocks interact with sunlight?* *Are astrology and astronomy the same thing?* *Are there any movies about space that get the science right?*
Stars give off electromagnetic wave signals in patterns. SETI scientists look for signals that break the usual patterns. Think about using a flashlight or laser pointer. How could you send a regular pattern and then interrupt it?	*I could repeatedly flash the light on for five seconds and off for five seconds and then interrupt the signal with a one-second flash.*
You may not be looking for interrupted patterns in radio signals from space, but you likely do notice many patterns in the day and night sky. What are some patterns that you can observe?	*the rising and setting of the sun in one day* *the phases of the moon during a month* *the change in the sun's place in the sky over the year* *lunar and solar eclipses*
The question of whether humans have had any contact with alien life is popular. Many books, some of them bestsellers, have been published that try to answer this question. You can likely find many of these books in your public library. How can readers enjoy these books and be scientifically literate about the topic?	*Try to be skeptical about what they read.* *Compare what the books say to what is said by science organizations.* *Try to distinguish facts from speculation.* *Do research to find out whether the story is plausible.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

KEY IDEA—Point out that, despite searching unsuccessfully for radio wave signals from intelligent aliens for decades, scientists' calculations lead them to infer that it is plausible that intelligent aliens do exist. To find out how likely it is that humans will eventually discover such aliens would require asking the right questions of the right experts. Although there are scientific experts on personal websites and social media, there are also many more people who are not reliable sources discussing such questions. Both the investigations and the reading selections in the unit ahead will help students advance to a place where they have more knowledge to apply to the scenario, and they will circle back to the topic of searching for intelligent alien life at the end of the unit.

LESSON 1

How are we connected to the patterns we see in the sky?

Previous Lesson

There is no previous lesson.

This Lesson

Anchoring Phenomenon

4 DAYS



We analyze how the Sun aligned with human-made structures on a particular day of the year and develop an initial model to explain this phenomenon. We consider how the position of the sunset on Earth can connect our daily lives to the sky and then brainstorm other interesting patterns in the sky. We bring in stories from family or community members about patterns in the sky they have seen or heard about and how these might be connected to the rhythms of human life. We use a jigsaw strategy with a series of podcasts to learn about ways that humans across cultures and throughout time have relied on and made connections to the sky, and we identify additional patterns. We develop a model of the parts and changes in the parts of the system that are needed to explain many of the patterns we have identified. We develop questions for the Driving Question Board (DQB), and then brainstorm ideas for where to go next.

Next Lesson

We will gather information from videos about Native American stories and changes in the day and night over 6 months. We will add more questions to the DQB. We will use our new understanding to develop initial models to explain why one star does not appear to move in the night sky.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

1.A Ask questions about systems in space that arise from observations of patterns in the sky.

1.B Obtain information from images, videos, and podcasts to describe patterns in natural phenomena of objects in the Solar System (and beyond), as seen from Earth.

1.C Develop an initial model of systems in space to describe patterns we observe in the sky.

What Students Will Figure Out

- Changing patterns in the sky connect to our (daily) lives and set the rhythms for life on Earth.
- Stories and analogies related to the sky are legitimate ways to preserve knowledge about the stars and planets and aid in observing and decision making.
- Light travels in a straight line; it must enter our eye in order for us to see the object it came from.

- The Earth rotates about its axis once every day and orbits the Sun once every year.
- In order to better explain and understand a complex system, we may need to view/visualize it from multiple perspectives.

Lesson 1 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	13 min	**NOTICE AND WONDER ABOUT A NEW PHENOMENON** Introduce a new phenomenon—the Sun aligning perfectly between buildings on a certain day at sunset.	A-C	8.4 Lesson 1 Manhattanhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Manhattanhenge Notice and Wonder poster, Word Wall poster, markers
2	10 min	**DEVELOP AN INITIAL MODEL TO EXPLAIN MANHATTANHENGE** Students create an initial model of what might be happening to cause Manhattanhenge and why we don't see it every day.	D-E	*Initial Manhattanhenge Model*
3	10 min	**SHARE OUT THE OBJECTS AND INTERACTIONS THAT CAUSE US TO SEE OR NOT SEE MANHATTANHENGE** The class gathers initial ideas for possible objects and interactions that cause the Manhattanhenge phenomenon to happen.	F	Parts & interactions in the system that help explain the Manhattanhenge Phenomenon poster, markers
4	8 min	**CONNECT THIS PATTERN TO THE SKY** Students brainstorm other patterns that they have experienced or heard about related to the sky.	G	sticky notes, Patterns and Phenomena in the Sky poster, markers
5	4 min	**NAVIGATION AND HOME LEARNING** Ask students to bring in stories from family or community members about patterns or other phenomena in the sky they have seen or heard about.	H	*Community Connections to the Sky*
				End of day 1
6	8 min	**NAVIGATION AND RETURN TO HOME LEARNING** Students share ideas they got from family and community members.	I-J	*Community Connections to the Sky*, sticky notes, Patterns and Phenomena in the Sky poster

Part	Duration	Summary	Slide	Materials
7	20 min	**PODCAST JIGSAW** Use a jigsaw strategy for podcasts to learn about ways that humans across cultures and throughout time have relied on and made connections to the sky.	K-L	*Making Sense of the Podcast Jigsaw*; *Reading- Podcast: Thebe Medupe - Rebirth of Selemela*; *Reading- Podcast: Annette Lee- As It Is Above, It Is Below*; *Reading- Podcast: Jessie Ferrari - Wombat Season*; *Reading- Podcast: Gerardo Aldana – The Descent of the Feathered Serpent*; headphones; 8.4 Lesson 1 Podcast: The Descent of the Feathered Serpent; 8.4 Lesson 1: Podcast: Wombat Season; 8.4 Lesson 1: Podcast: Rebirth of Selemela (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**); *Listening Group Roles Reference*; audio player
8	14 min	**MAKING SENSE OF PODCASTS AS A CLASS** Facilitate a Building Understandings Discussion to generate ideas about why studying the sky is relevant and about specific patterns in the sky.	M	*Making Sense of the Podcast Jigsaw*, sticky notes
9	3 min	**NAVIGATION AND EXIT TICKET** Give students a chance to reflect on the podcasts before we begin modeling the next time we are together.	N	blank piece of paper
				End of day 2
10	9 min	**MODEL PATTERNS OR PHENOMENA IN THE SKY INDIVIDUALLY** Students choose a pattern to model on their own.	P	*My Initial Model to Explain: _____*, *Systems Modeling Scaffold* (optional), Patterns and Phenomena in the Sky poster
11	6 min	**COMPARE INITIAL MODELS** Students share their model with a partner and make revisions.	O-P	*My Initial Model to Explain: _____*, *Systems Modeling Scaffold* (optional), Patterns and Phenomena in the Sky poster

Part	Duration	Summary	Slide	Materials
12	25 min	**BUILD A CONSENSUS MODEL OF SYSTEMS IN SPACE** Conduct a gallery walk. Build an initial consensus model of systems in space that can explain patterns that we see.	Q-T	*Initial Models Gallery Walk*, *Systems Modeling Scaffold* (optional), Initial Consensus Model chart, markers
13	5 min	**NAVIGATION AND STOP AND JOT** Give students a chance to pre-think of some questions for the DQB with a Stop and Jot.	U	
				End of day 3
14	27 min	**BUILD THE DRIVING QUESTION BOARD (DQB)** Navigate into the day and create the Driving Question Board.	V-Y	marker, sticky notes, DQB, markers
15	13 min	**BRAINSTORM NEXT STEPS** Brainstorm investigations we want to do and data we think we will need in order to answer the questions on our DQB.	Y	Ideas for Future Investigations and Data We Need chart, markers
16	5 min	**NAVIGATION AND OPTIONAL HOME LEARNING** Consider where we should go next.	Z	*Lesson 1 Community Guide for Looking at the Sky*
				End of day 4

Lesson 1 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • *Initial Manhattanhenge Model* • *Community Connections to the Sky* • *Making Sense of the Podcast Jigsaw* • *Reading- Podcast: Thebe Medupe - Rebirth of Selemela* • *Reading- Podcast: Annette Lee- As It Is Above, It Is Below* • *Reading- Podcast: Jessie Ferrari - Wombat Season* • *Reading- Podcast: Gerardo Aldana - The Descent of the Feathered Serpent* • headphones • blank piece of paper • *My Initial Model to Explain: _____* • *Systems Modeling Scaffold* (optional) • *Initial Models Gallery Walk* • marker • sticky notes • *Lesson 1 Community Guide for Looking at the Sky*	• sticky notes • *Listening Group Roles Reference* • audio player	• 8.4 Lesson 1 Manhattanhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Manhattanhenge Notice and Wonder poster • Word Wall poster • markers • Parts & interactions in the system that help explain the Manhattanhenge Phenomenon poster • Patterns and Phenomena in the Sky poster • Initial Consensus Model chart • DQB • Ideas for Future Investigations and Data We Need chart

Materials preparation (40 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Reminder about supporting students with visual disabilities: This unit uses images as data and phenomena that often include changes in light or color of an object in the sky. You will need to make accommodations so that students who are blind or have low vision can access this data. Depending on your students' needs, suggested modifications include enlarging and/or brightening the provided digital versions of these photos or using alternate text descriptions.

Test the podcasts: 8.4 Lesson 1 Podcast: The Descent of the Feathered Serpent; 8.4 Lesson 1: Podcast: Wombat Season; 8.4 Lesson 1: Podcast: Rebirth of Selemela; 8.4 Lesson 1: Podcast: As It Is Above, It Is Below (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**) ahead of time and decide how

students will listen to them in small groups. If students play the podcast directly from YouTube, they can turn on closed captioning. See guidance callout for suggestions.

Each student should receive the handout of one of the transcripts or can access the color version in the student edition.

Review the unit front matter for an overview of how systems and systems models, scale proportion and quantity, and patterns are scaffolded in this unit.

Review the unit front matter for an overview of how this unit is designed to help students see why the patterns in the sky are relevant to their lives, their communities, and life on Earth.

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Manhattanhenge Notice and Wonder
- Word Wall
- Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon
- Phenomena and Patterns in the Sky
- Podcast Wonderings
- Initial Consensus Model for Explaining All of Our Different Phenomena and Patterns
- Driving Question Board
- Ideas for Future Investigations and Data We Need

If you haven't already done so this year, download the *Communicating in Scientific Ways* file from the OpenSciEd website, print it, and post it in your classroom or add it to students' notebooks. The file can be used as a poster or a handout.

Be sure you have materials ready to add the following words to the Word Wall: *pattern, change in perspective*. Do not post these words on the wall until after your class has developed a shared understanding of their meanings.

Lesson 1 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students begin with a phenomenon that is directly connected to their experience but with a twist: a sunset that aligns with human-made structures on a certain day but not other days. But we quickly expand away from this phenomenon to think about other patterns in the sky. By the time students develop models on Day 3, they should be thinking about any and all patterns in the sky that they think might be connected to systems in space and their lives or the lives/histories of other people on our planet. In Lessons 2–7, students will model and explain: (a) seasonal patterns of the Sun's path across the sky and the related phenomena of seasonal temperature changes in the Northern and Southern Hemispheres; (b) changing patterns of constellations visible in the night sky across the year from different places on Earth; (c) the periodicity of lunar phases; (d) solar eclipses; and (e) predicting when solar eclipses would tend to occur. In addition, by employing the practice of modeling complex phenomena students will motivate the need to have multiple perspectives in order to make sense of the interactions between the objects in the system at multiple scales. When making the Ideas for Investigations poster and during investigations in later lessons, students

will identify the need to not just mechanistically model on paper but also create two- and three-dimensional models to showcase these perspectives and interactions.

By drawing out a broader range of patterns in the sky during this anchoring phenomena routine, a greater number of student questions specific to this performance expectation bundle can be addressed through investigations throughout the unit. Furthermore, this broad anchor increases student engagement and leverages necessary student prior knowledge from the Physical and Earth and Space Sciences from the K–2 and 3–5 grade bands of the NRC Framework. It is necessary in this lesson to revisit briefly what students have figured out in previous grade bands.

See the unit front matter for more details on the prior knowledge students may be bringing into the classroom elementary DCI elements and how the initial models developed in this lesson will connect to future lessons.

Where We Are NOT Going

Students may suggest sudden events like asteroid collisions or supernovae. The focus of this unit is explaining repeating patterns, so while there may be the opportunity to read about these events over the course of the unit, students will not be modeling or explaining them.

Students may also broaden their questions on the DQB to include things they have heard about in space, like black holes or supernovae. Stars and stellar evolution are high school grade band and are not covered in this unit. Put these questions up on the DQB now, but know that they may end up unanswered. Encourage interested students to research unanswered questions at the end of the unit.

The words *patterns* and *perspective* are introduced formally in this lesson but will likely have already been built out in other units, but in different contexts. In future lessons, there will be more vocabulary to add to a Word Wall and/or personal glossary. But other than *patterns* and *perspective*, in this lesson, accept and build on students' everyday words, using scientific vocabulary like *lunar* or *annual* only if students are using these words fluently already. When coming to consensus on the meaning of Word Wall words, be sure to co-construct the meaning of each word with your students.

It is not until the fourth lesson set of the unit , that we will define, as a class, what we mean by the Solar System.

LEARNING PLAN FOR LESSON 1

1. Notice and wonder about a new phenomenon.

13 MIN

Materials: science notebook, 8.4 Lesson 1 Manhattanhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Manhattanhenge Notice and Wonder poster, Word Wall poster, markers

Additional Guidance

Connections to Me and My Community: In this lesson, we begin by collaboratively observing a phenomenon that can connect to our daily lives: Manhattanhenge. Support is provided for how to highlight local manifestations of this phenomenon. Students consider how changes in the Sun is one of many changing patterns in the sky and brainstorm other patterns they have experienced or heard about. Expanding outward from their own experience, students draw on funds of knowledge to bring in stories from family or community members about patterns they have seen or heard about in the sky and how these might be connected to the rhythms of life on Earth. Expanding outward from our local community, we listen to a series of podcasts to learn about ways humans across cultures and throughout time have relied on and made connections to the sky. Support is provided for how to help students make connections and build on their own cultural resources in processing these podcasts.

Review the front matter for the unit for an overview of how this unit is designed to help students see why the patterns in the sky are relevant to their lives, their communities, and life on Earth.

Introduce a new phenomenon. Present **slide A**. Launch the unit by sharing about a new phenomenon you encountered on the news. Depending on the time of year you teach the unit, adapt what you say to fit whether it already happened or is happening soon. Say, *I was watching the news the other day and heard about thousands of people going to New York City on the same day to watch the sunset. Ask, have any of you heard of something like this?* Take a show of hands.*

Alternate Activity

To make this phenomenon even more locally or culturally relevant, you could search the internet for a henge that is local or of cultural significance to your students. Manhattanhenge is just one example of henge phenomena with buildings/structures and Sun alignment. Other famous henges include Stonehenge (England), Chicagohenge (Illinois State), Newgrange (Ireland), El Castillio pyramid at Chichén Itzá (Mexico), or Abu Simel (Egypt). However, many smaller henges occur all over the world, such as the woodhenge at Cahokia Mounds (Illinois) or rock wall henges in North Stonington, Connecticut. If you do this option, you will need to adjust the maps.

Watch a video of Manhattanhenge. Present **slide B**. Have students make a Notice and Wonder T-chart for Manhattanhenge in their science notebook. Students should record in their T-chart what they notice and any wonderings they have after watching the video. Show the video 8.4 Lesson 1 Manhattanhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). You might want to play the video clip more than once.*

*** Attending to Equity**

This phenomenon and others that students explore in this unit are strictly visual and based on changes in color and light. Consider the needs of your students and how you will make visual phenomena accessible to all of your students, including those with color blindness or low vision, those who are blind, and/or those with other visual impairments. Possible modifications include providing a tactile representation of the changes being investigated, alternate color schemes, increasing the size and/or brightness of images provided digitally, and using descriptive alt text. Work with your students' IEP or 504 caseworker to support your students' needs.

*** Attending to Equity**

Universal Design for Learning: Allowing students to *express* their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas. Keeping a science notebook allows students a space in which to reflect and communicate their

Additional Guidance

When you play 8.4 Lesson 1 Manhattanhenge make sure to either pause at the beginning and read or out loud from here, the text presented on the paper: "Twice a year the sun sets in exact alignment with the city grid of Manhattan. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) The calculated architecture of the city and the celestial body of the sun form a visualization and a connection between fabrication and nature. The urban phenomenon here is called 'Manhattanhenge'."

Science Notebook



This is the first use of the science notebook for the new unit. You may need time to organize a new section in the notebook. How to set up the section will vary depending on how you've structured the components of your notebooks, such as the table of contents and how to note the start of a new unit. We recommend students do the following:

- Reserve a blank page at the start of the unit, to be titled on Day 4 of this lesson when students are given the unit question.
- After the title page, reserve 2 pages (4 pages front-to-back) for the table of contents (unless all tables of contents are at the front of the notebook).
- Reserve 10 pages (20 pages front-to-back) for the Progress Tracker pages.
- Number the pages so everyone begins the first investigation of the unit on the same page number.

For more information on *Science Notebook Management*, refer to this section of the *Teacher Handbook*.

Share out noticings and patterns we noticed. Show **slide C.** Have students go public with any patterns they noticed or important noticings during Manhattanhenge. Record students' responses on the Manhattanhenge Notice and Wonder poster.

Suggested prompts	Sample student responses
Why do you think people feel connected to this phenomenon?	*Answers will vary. Accept all answers.*
What else did you notice from the Manhattanhenge video?	*The Sun moved across the sky and right into the middle between the buildings.*
*What are you wondering about now?**	*How is this city arranged?* *Does this happen every day? Month? Year?* *If it happens more than once, is it always on the same day?* *Does this happen in other places?* *Is it only on certain streets?*

developing understandings about science ideas and to track changes in their understandings. Students should be encouraged to record their ideas using linguistic (e.g., written words) and nonlinguistic (e.g., photographs, drawings, tables, graphs, mathematical equations, measurements) modes. This is especially important for emerging multilingual students because making connections between written words and nonlinguistic representations helps students generate richer explanations of scientific phenomena.

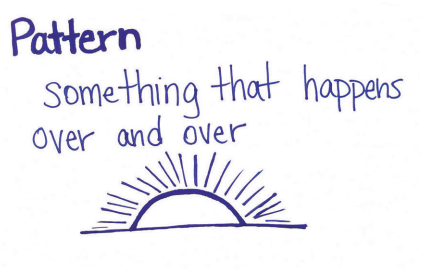
*** Supporting Students in Developing and Using Patterns**
Make sure when you are defining a pattern you do it in the language of your class, a pattern is a repeated instance. This is something that students should have coming in (from prior grade bands and units), but because we are thinking on such different scales of time and size, it is important to make sure students acknowledge what these words mean, especially if there are students new to the class and/or new to English.

Listen for students to share about how the video said Manhattanhenge does not happen every day. If students say this, push them to explain what they mean by "it doesn't happen every day" if students do not ask, *They said in the video that Manhattanhenge doesn't happen every day. What does that mean?*

Suggested prompts	Sample student responses
Whoa! What do you mean, the Sun doesn't set every day?	*No, the Sun sets, but they can't see it through the buildings and down the street, every day of the year.*
But we think it will happen again?	*Yes, no, maybe every year?*
Do we think that Manhattanhenge is something that happens more than once?	*Yes, it is a pattern.*

Look for students to suggest that changes in when sunset occurs (and where it occurs on the horizon) is a seasonal pattern. Students might not use the word *pattern* but may say that it happens every day or that they have seen it happen over and over. Get agreement from the rest of the class on this being something that happens every year (or over and over again) by asking for a show of hands.

Add *pattern* and the co-constructed class definition to the Word Wall. Your definition might be something like "*Something that happens over and over is called a* ***pattern***. Remind students that the Word Wall is a place where we can record our growing understanding of words, and we will come back to it frequently to add more words or revise our understanding of words based on what we figure out in class.*



Say, Let's see if we can try and explain what is happening when we can see Manhattanhenge and why we can't always see it and why it is a pattern!

2. Develop an initial model to explain Manhattanhenge.

10 MIN

Materials: science notebook, *Initial Manhattanhenge Model*

Orient to the model scaffold as a class. Display **slide D.** Spend three minutes explaining using both maps as a model scaffold. Distribute a copy of *Initial Manhattanhenge Model* to each student. Don't have students put this handout in their notebooks yet. You will be collecting them at the end of the period. Decide whether you will put the handout *Initial Manhattanhenge Model* or if you will use the images on slide D.

Say, *You are going to use this handout to develop a model to show what interactions are happening with the objects in the system to cause the Manhattenge to happen on certain days but not others. Standing at the corner of 34th Street and 5th Avenue and facing northwest is where people say you can get some of the best views of the Manhattanhenge phenomenon. There are two maps of New York City, both showing this location. If you look at the photograph of Manhattanhenge, can you see the Empire State Building? Now try and find the Empire State Building on your maps. When looking northwest (toward the water) on May 31st at 8:17 p.m., this is what the photographer saw.*

Individually develop an initial model to explain Manhattanhenge. Display **slide E.** Give students 5 minutes to complete *Initial Manhattanhenge Model*.

Additional Guidance

If students feel inhibited by the maps or need additional space, you can have them record their ideas on a blank piece of paper instead of on the handout.

Collect *Initial Manhattanhenge Model* before the end of the class for a formative assessment.

3. Share out the objects and interactions that cause us to see or not see Manhattanhenge. 10 MIN

Materials: Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon poster, markers

Turn and talk to share out parts and interactions from individual initial models for Manhattanhenge. Display **slide F.** Say, *if what we noticed about Manhattanhenge is a pattern, let's try and identify what is causing this to happen.* Allow a couple of minutes for students to turn and talk with a partner about the questions on the slide. Circulate the room as students are sharing and look for students to be sharing equitably in their partnerships and remind them to use their model to support their discussion.

- What objects are interacting to cause us to see Manhattanhenge?
- What changes or interactions in the system can help explain why we only see Manhattanhenge on certain days of the year?

Facilitate a whole-class Initial Ideas Discussion. Continue to display **slide F.** Have out parts and interactions for explaining Manhattanhenge as a class. As students share the parts and interactions, add their ideas to a poster titled Manhattanhenge with parts and interactions below it as T-chart headings.

* Supporting Students in Developing and Using Cause and Effect

If your students have completed *OpenSciEd Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*, explicitly make the connection here between cause-and-effect relationships and patterns. Consider engaging students in making these connections by asking, *How does cause and effect relate to patterns? How could you use the cause-and-effect sentence frames that we used to explore the speaker to talk about patterns in the sky?* Students might suggest (or you might introduce) a modified sentence frame such as this: When *something in space changes*, we will observe *this pattern*. Review the unit front matter for an overview of how to scaffold crosscutting concepts in this unit.

Key Ideas

Purpose of Discussion: The purpose of this discussion is for students to determine parts and interactions needed to develop a model for why Manhattanhenge happens or doesn't happen. The class will not make a diagrammatic model of this system at this time. Rather, create a running initial list of what they think is needed for explaining this phenomenon before branching out to other phenomena/patterns in the sky that similar parts and interactions might be needed for as well. Additionally, this discussion surfaces recurring themes for the unit of perspective and scale.

Listen for the following and add them to the "Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon" poster as the class agrees on them.

- A person (eye) to see the phenomenon
- Buildings
- Light/light rays traveling in straight lines from the source (the Sun)
- Changes in the angle of these light rays relative to the person
- Motion of the Sun/Earth
- Changes in the position/orientation of the Earth relative to the Sun
- Multiple perspectives
- Multiple scales

Don't worry about whether students are in agreement on the direction of the sunset (to the northwest) at the time of the Manhttanhenge. Students will explore patterns in how the direction of a sunset changes over the course of the year and over many years in Lesson 2.

Suggested prompts	Sample student responses	Follow-up questions
Let's consider the parts of the system that are needed to explain why we see Manhattanhenge is happening on one day but not another. What are some parts that need to be in our model in order to explain what we see?	*We need people to see the phenomenon.* *There needs to be people, and those people need to be in certain spots between the buildings!**	*Do I hear you saying we need to have buildings and people in our models at a particular position to be able to see the Manhattanhenge phenomenon?*
If the Sun sets on both days in our models, what is happening between the Sun and our eyes that allows us to see Manhattanhenge on one day but not the next?	*The light (or light rays) are blocked by buildings on one day at sunset but not another.*	*How did you show an unblocked path of light coming to our eyes in one case but not another?*
How did you draw the light rays in your models? If your students have had Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit), say, What did we figure out about how to draw light rays in One-way Mirror Unit, curvy or straight?	*straight*	*And what did we say is the source of those light rays?*
We talked about light rays and that they are coming from the Sun. But where exactly do we put the Sun in a model at this scale? What might be some challenges or limitations with representing the Sun in a model at this scale? I heard you say light rays, but what is the source of those light rays? Where would you put the Sun in our model so that it appears to fit between the buildings, close to the people seeing Manhattanhenge?	*Yes, we need to put the Sun way far away out in space and we need to show it between the buildings.* *Is there a way to include two places and sizes in our model?* *Accept all answers.*	*That is an interesting question for us to start considering, and we don't need to resolve it yet. It has already helped us consider what scale and perspective we use in a model is most useful. Since we all agree the Sun is a part in the system that causes this phenomenon, let's keep track of that for now.**

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

The crosscutting concept of Scale, Proportion, and Quantity is central to this unit and to understanding space systems. Because our perspective on Earth is limited, phenomena that can be observed at one scale—for example by simulating the whole Solar System at once from a perspective above the system—may not be observable from our perspective. Many of the familiar patterns and phenomena we see on Earth are symptoms of this limitation of perspective and our inability to observe the system at scale. It is not until the fourth lesson set of the unit, that we will define, as a class, what we mean by the Solar System.

Review the unit front matter for an overview of how to scaffold crosscutting concepts in this unit.

Additional Guidance

In grade four, students have developed a model to describe how light reflecting from objects and entering the eye allows objects to be seen (4-PS4-2). This model they reused and developed further in *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*. In particular, they developed the idea from PS4.B that the path that light travels can be traced as straight lines. You are trying to elicit these previously developed ideas, and you are also trying to make sure that the class agrees on these before moving on. This is an 8th grade unit, so it is important to surface these ideas to help ensure that all students in the class have an understanding that light travels in straight lines, can reflect off objects, and enter the eye (which results in seeing the object) before moving on and building off of these ideas by using models in service of explaining these patterns for more complex phenomena.

Take a moment to generalize out to broader phenomena and elicit student knowledge from earlier grades.

Suggested prompts	Sample student responses
We know that Manhattanhenge doesn't happen every day, but the Sun still sets even if it isn't between the buildings. What is the same and what is different or changing about the parts of the system when we don't see the henge?	*The Sun would still set on the horizon each day; it just wouldn't be between the buildings.*
What do you think is happening with the objects in the system to cause the Sun to set every day? Or, What is going on with the Earth each day for a sunset to happen in the first place?	*The Earth is turning.*
Can someone show me with their hands what _____ means when they say the Earth is turning?	*(Watch for a spin of the Earth around itself.)*
Are there any other interactions in the system with other objects/parts that we should take into account in order to explain changes happening over something like a month? What else is changing over that period of time?	*We learned in 5th grade that the Earth goes around the Sun each year.* *The Earth would orbit part of the way around the Sun in a month.*
Can someone show me with their hands what _____ means when they say the Earth goes around the Sun?	*(Watch for an orbit of one object [Earth] around another [Sun].)*

Additional Guidance

The NGSS DCI Element ES1.B for second grade says: Seasonal patterns of sunrise and sunset can be observed, described, and predicted. For fifth grade it says: The orbits of Earth around the Sun and of the Moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily and seasonal changes in the length and direction of shadows; phases of the Moon; and different positions of the Sun, Moon, and stars at different times of the day, month, and year.

The spin of the Earth, and the orbit of the Earth around the Sun are both fifth grade standards, so do not spend too much time on this, as you are simply trying to elicit these previously developed ideas. This is an 8th grade unit, so it is important to surface these earlier grade band DCI elements to help ensure that the all students in the class have this understanding before moving on and building off of it for more complex patterns and explanations of models in this unit and that these ideas will be built upon by using models in service of explaining these patterns for more complex phenomena.

At this point, you should have a running list of parts/interaction on "Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon" on a poster. See the previous key ideas box for guidance on what should be included on that poster.

Say, *It is pretty wild that we can connect this pattern to changes happening to parts of this system in space. We've already moved to visualizing what is happening in this system from a perspective that is way bigger than what we can see from where we are located right now on Earth.*

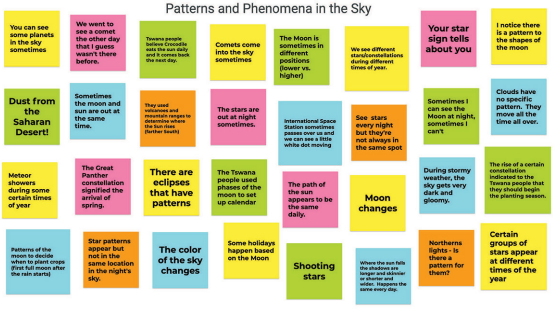
Say, *Let's pause here. We have identified a lot of parts of the system that causes Manhattanhenge and how to describe how they would change. Before we commit to making a more diagrammatic representation of the system from different perspectives/views, let's think about all the other things beyond just this one phenomenon. We might want to be able to explain with a system that includes some of these parts.*

4. Connect this pattern to the sky.

8 MIN

Materials: sticky notes, Patterns and Phenomena in the Sky poster, markers

Brainstorm additional patterns in small groups. Organize students into groups of 4–5. Present **slide G** and ask, *Is there anything else like that, where something happening way out in space is changing the patterns of what we see in the sky either during the day or during the night? Discuss this in your table group.* As you circulate the room, accept all responses, but encourage students to focus on patterns they have seen or experienced. Don't worry if this list is not exhaustive; students will return to it twice in the next few days with new information.



After discussing in small groups for a couple of minutes, have students record their ideas on sticky notes. As students work, make sure that a piece of chart paper labeled Patterns and Phenomena in the Sky is hung near the front of the room.

Ask each group to put their stickies on this poster. Accept all ideas.** You may see things like these:



- different shapes of the Moon
- eclipses
- tides
- astrology, zodiac, star signs
- holidays
- meteor showers

*** Attending to Equity**

Universal Design for Learning: Generating related phenomena is a key element of the Anchoring Phenomenon routine. Tapping into prior knowledge and experiences broadens students' thinking related to this phenomenon and helps make the unit phenomenon become more personally meaningful to each student. It is OK at this point if students share phenomena that are not all that related (e.g., a weather event). This provides students access by supporting student *engagement*.

Assessment Opportunity

Building towards: 1.A Ask questions about systems in space that arise from observations of patterns in the sky.

What to look/listen for: Use this as a pre-assessment to gauge how much your students already know about space. Listen for students to list observable phenomena connected to not only the motion of objects in the sky/space but also the appearance. Objects may include the Sun, Moon, stars, and planets. Some students may be suggesting comets and galaxies, while other students might suggest that the Sun goes around the Earth.

What to do: Accept all ideas. If your students need support with foundational understandings (from earlier grade bands) about the motion of objects, make sure to take note in this lesson and then pause and establish these ideas when we model the Sun-Earth system in Lessons 2–4. If your students are eager to know more about other ideas, such as black holes or exoplanets, there are a number of optional readings and podcasts throughout this unit to connect students to myriad space-related phenomena.

As students are sharing their patterns and phenomena, push them to explain the phenomenon and connect it to something observable. If they struggle to do this, ask them, *What are the objects connected to the pattern/phenomenon? What would we be able to see happening?* Then give students time to respond to this feedback and create more sticky notes or revise what they wrote on their sticky note already with more detail, objects, observations, or connections.

Additional Guidance

Expect that your students will also include Sun-related patterns on their sticky notes, such as day length, sunrise, sunset, seeing the Sun midday, seeing light rays, etc. Collect these ideas with the others on your poster since students will build on these ideas as they work through this unit. See the "Where We Are Going" section for a specific explanation of how this lesson builds off DCI elements from prior grade bands such as these Sunrelated patterns.

*** Attending to Equity**
Universal Design for Learning: Allowing students to *express* their ideas using multiple modalities supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas. During moments when students are tasked with expressing their ideas, allow them to do so through linguistic (oral and written language) and nonlinguistic (e.g., drawings, graphs, symbols, gestures) modes. For example, you might suggest sketching a picture on the sticky note to a student who is having trouble articulating a pattern they have observed related to the Moon. Providing students, emerging multilingual students in particular, with such opportunities allows them to use all their resources to express meaning.

5. Navigation and Home Learning

4 MIN

Materials: *Community Connections to the Sky*

Assign home learning. Present **slide H**. Say, *We have seen a lot of stuff in the sky and have a lot of ideas about what is going on to cause some of those patterns/phenomena. We will come back to this tomorrow but let's see if we can get more ideas first. Our friends and family may have seen things or heard about things that we haven't experienced. There might be stories our family or community know about things in the sky that go back even longer in time. Let's pull in those resources.**

Distribute *Community Connections to the Sky*. Say, *Tonight, go home and poll your friends and family members. First, share with them what we have been talking about and share an example of a pattern, such as Manhattanhenge. Let them know that this is not about weather but about patterns we think are connected to space. Then ask them these questions:*

1. *What patterns or phenomena have they seen in the sky?*
2. *What stories have they heard from their family and community about patterns others have observed in the sky or about things on Earth that are connected to patterns and objects in the sky?*

*** Attending to Equity**
Universal Design for Learning: Framing students' families and communities as legitimate funds of knowledge can serve multiple purposes for student *engagement*. It can: (1) help students feel like they belong in the science classroom by situating their family and community knowledge as productive resources for science; (2) engage students' families in conversations about what is happening in the classroom; and

End of day 1

(3) help students make connections between the science classroom and their everyday lives.

6. Navigation and Return to Home Learning

8 MIN

Materials: *Community Connections to the Sky*, sticky notes, Patterns and Phenomena in the Sky poster

Return to home learning. Display **slide I**. Have students share the ideas they got from their family and community with the people at their table, and then record at least one new idea per table on a sticky note. Students should then add their sticky note(s) to the Patterns and Phenomena in the Sky poster. Look for students to add things like these: Moon phases, star patterns, shooting stars, eclipses, comets, satellites, jet streams, airplanes, sunsets, green flash, clouds, rainbows, Northern Lights, planets, Milky Way, other galaxies, days, nights, moonlight, UFOs, origin stories, celestial navigation.*

Additional Guidance

To keep the focus on space rather than on clouds and weather, you can respond to such suggestions by saying, *Wow, that's an interesting pattern! What about patterns that we think are connected to systems in space?*

Say, *Wow, we got a lot of new ideas by polling our friends and families. Even though our friends and families have more experience than we do, they haven't been everywhere or around for that long when we think about how long humans have been observing the sky. How could we find out more about what patterns people across the world have observed in the sky over human history?* Present **slide J** and have students turn and talk. Listen for students to suggest different modalities of storytelling, like videos, art, audio recordings, or podcasts.

Forecast the podcast jigsaw as a way to further expand our pool of experiences. Say, *We can't go back in time, but people from every culture have been observing the sky from all over the globe for thousands of years. Maybe they saw other patterns connected to the sky that we could add to our Patterns in the Sky poster.*

*** Attending to Equity**
Supporting Emerging Multilingual Students: Allow and encourage students to speak using both content-specific and everyday words and phrases when expressing their ideas. This helps students fully express themselves, allowing others to question, evaluate, and build off their ideas. Switching back and forth between different registers is especially important for emerging multilingual students because it helps them draw on their full range of meaning-making resources.

7. Podcast Jigsaw

20 MIN

Materials: science notebook, *Making Sense of the Podcast Jigsaw*, *Reading - Podcast: Thebe Medupe - Rebirth of Selemela*, *Reading - Podcast: Annette Lee - As It Is Above, It Is Below*, *Reading - Podcast: Jessie Ferrari - Wombat Season*, *Reading - Podcast: Gerardo Aldana - The Descent of the Feathered Serpent*, headphones, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), *Listening Group Roles Reference*, audio player

Prepare for podcast jigsaw.* Present **slide K**. Introduce the podcasts and the close listening protocol using the slide. Say, *Today we are going to listen to a podcast that was recorded by present-day scientists about their scientific research and the cultural identities of their people or the communities they study and work with. Each of these podcasts highlights a community from a different region on Earth. We will use a close listening protocol to help us obtain information through our noticings, gather our wonderings, and then make connections to not only the phenomena discussed in each podcast but also the community represented and our own connection to space and the sky.***

*** Attending to Equity**
Whenever we consider cultural identity in the classroom, it is important to avoid framing this identity as static and homogenous and instead to recognize all people as having multilayered and multicultural identities. The podcast interviewees are not only celestial storytellers but also

Walk through the close listening protocol below and field any questions students have. Depending on how much time you have, warn students to keep pauses short.

Before	• Look at the title of your podcast and discuss with your group. What does the title tell you about what will be in the podcast? • What is a question you have that you hope the podcast will help answer?
During	• Listen carefully, following along with the transcript. • Highlight or underline words, phrases, and ideas that you have never heard before or that you want to know more about. • Each person in your group will be allowed one **pause request**. When you hear something that you want to discuss or have clarified, raise your hand to use your pause request.
After	• Look at the title of your podcast again. Now that you have heard the podcast, why do you think the podcast producers chose this title? • Respond to these questions on the handout and be ready to share with the class.

Organize students into small groups of 4–5 and assign them one of the following podcast links. Make sure that you distribute to each group the appropriate handout with the podcast transcript and accompanying images. If your class is larger than 25, you can choose to assign two groups to a podcast or increase the group size, depending on the number of audio players you have available. The podcasts are designed to be comprehensible by a range of 8th grade students. You may want to assign specific podcasts to specific students or allow students to choose what text they read.* Distribute *Reading- Podcast: Thebe Medupe - Rebirth of Selemela*, *Reading- Podcast: Gerardo Aldana - The Descent of the Feathered Serpent*, *Reading- Podcast: Jessie Ferrari - Wombat Season* , or *Reading- Podcast: Annette Lee- As It Is Above, It Is Below* (printed for students so they can mark up the text) to each student, or alternately, direct students to the corresponding podcast in their Student Edition book to view the images in color. Point out to students that at the end of each podcast transcript there is a Word Bank.

- *Reading- Podcast: Thebe Medupe - Rebirth of Selemela* (less complex)
- *Reading- Podcast: Gerardo Aldana - The Descent of the Feathered Serpent* (mid-range complexity)
- *Reading- Podcast: Jessie Ferrari - Wombat Season* (mid-range complexity)
- *Reading- Podcast: Annette Lee - As It Is Above, It Is Below* (most complex)

(See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

present-day research scientists, historians, and artists. The interviewee in *Reading - Podcast: Jessie Ferrari - Wombat Season* shares their trans and gender fluid identity—this can send a powerful message that anyone can be a scientist, and the sharing of identities makes scientific discourse richer. It is easy to tokenize cultural stories. The goal is to respect but not oversimplify differences in the podcasts, classroom, and world.

*** Attending to Equity**
Universal Design for Learning: To support students in map reading and to orient students to the location of each podcast, hold up a larger globe if you have one. You may want to also talk about where your classroom would be on the globe. Providing physical objects and spatial models to convey perspective can help support representation, according to the UDL framework.

*** Attending to Equity**
Universal Design for Learning: Providing students the opportunity to choose the level of perceived challenge can support *engagement*, help develop self-determination and pride in accomplishment, and increase the degree to which they feel connected to their learning.

Additional Guidance

Note that while the scientific information in each of these podcasts is equally rigorous, they are written at various comprehension levels to support differentiation. The information in the least complex of the podcast is more concrete, while the others require more careful listening. The information in the most complex podcast is more abstract. You may choose to group students strategically so that students who need more support with obtaining information from scientific texts and listening comprehension are distributed among mixed-expertise groups assigned readings of mid-range complexity, while students who are looking for a challenge are in groups assigned podcasts at a higher complexity level.

Decide ahead of time how you want students to listen to the podcasts. Here are some possible options:

- each student with their own device and a pair of headphones;
- groups each gathered around a computer or music player with the volume low in different parts of the classroom;
- groups each gathered around a computer or music player at their table with a splitter that allows them to connect multiple pairs of headphones; or
- groups each gathered around a computer or music player in separate rooms.

Consider assigning students roles to keep every student on task and enforce the use of the close listening protocol. We suggest the following roles for a group of 5, also found on *Listening Group Roles Reference*:

- **Progress monitor.** This person periodically asks others to take the measure of the group's progress. This includes watching the time to keep the group on track. Some questions the progress monitor might ask are the following:
  - "What can we say we've accomplished so far?"
  - "What do we still need to know or do to accomplish this task?"
  - "We have _____ minutes left. What can we do in that time to accomplish our task?"
- **Big ideas person.** The role of this student is to relate the podcast to the question we are trying to answer.
  - "How does what you said relate to _____?"
  - "How does this change the way we're thinking about _____?"
- **Clarifier.** This is a role of monitoring everyone's comprehension about one or two key science terms. The clarifier might ask questions such as these:
  - "Do we know what the word _____ refers to?"
  - "Can we put it into our own words?"
- **Questioner.** This person asks probing questions during the activity. The questioner listens for questions posed by other group members and then revoices the questions to make sure that the whole group takes a moment to hear and entertain questions from everyone. This is not a role that students find easy, so it helps to provide them with question stems such as these:
  - "What does it mean that _____?"
  - "How do we know that _____?"
  - "So, what I think you are saying is _____. Is that right?"

*** Attending to Equity**

Universal Design for Learning: Reading the transcript of the podcast as they are listening to it provides students multiple *representations* (audio with closed captioning, photos, and text) of the information, which could be harder to interpret from audio alone. Consider posting a digital copy of the podcast and transcript for students who are interested in listening to it again outside of class and encourage them to share both the transcript and podcast with others in their family. Some students may find a variety of ways it is relevant to themselves and to others in their community. Examples include the stories of what drew these people into their careers, international connections, a diverse group of scientists, and/or thinking about their community connections to the sky, and in one's own local area, over many years.

- **Conductor.** This role might not exist in a group of 4. This person monitors airtime of people in the group. The conductor is allowed to control who has "the floor" with the goal of ensuring that everyone gets a chance to talk and that everyone takes time to listen. The conductor will also be in charge of playing/pausing the podcast when requested.

If you choose to assign roles, use *Listening Group Roles Reference* to help students understand their roles in the group.

Listen to the podcasts.* Pass out *Making Sense of the Podcast Jigsaw* and/or display **slide L** and have students work on the questions in their small, expert groups after they listen to the podcasts. Students can respond to these questions in their notebooks, on the handout, or as part of a verbal discussion:

1. How did the people you learned about: 1) observe the sky and keep track of what they saw and 2) use their observations of the sky?
2. What patterns in the sky did you hear about in the podcast? Why did the people you learned about observe those patterns?
3. How can observing the sky help us better understand our own planet and our own lives?
4. How do the patterns that we see in the sky help set the rhythms of our lives?

Alternate Activity

These podcasts represent just a tiny glimpse into some of the ways that patterns in the sky have set the rhythms for human life across time and space. This is an opportunity to localize this phenomenon for students. Consider inviting a local expert (or several) to come in and give a live interview to the class as an additional point of data. Ask students if they know anyone in their family or community who might be interested. Consider reaching out to local astronomy clubs, universities, community leaders, and/or Indigenous elders. The goal is to help students make connections about why humans study the sky and to build on their own multicultural resources to process the information in the podcasts.

If you go this route, have students prepare a list of questions beforehand and make a plan for how to distribute the work of asking the questions among students. Consider recording the interview and making the file available online as a podcast that the class can share with friends and family. (One resource that could support this is the NPR Student Podcast Challenge). (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Students will get another opportunity to make their own podcasts later in the unit.

Additional Guidance

These podcasts were chosen to begin this unit for a variety of reasons.

- **Motivation:** Understanding how humans across time and space have articulated the relationships between our lives and the sky can help students form connections about why the content matters to them.
- **Understanding:** Considering more than one perspective on a phenomenon makes our understanding of that phenomenon more robust.
- **Identity:** Highlighting more than one legitimate cultural way of knowing helps students from all backgrounds see an identity for themselves in science.

Present these podcasts to students not as stories about ancient or outdated ways of thinking about the world, but as legitimate, living bodies of knowledge. This knowledge is not lesser than but rather a complement to Western scientific ways of knowing. Humans have always been driven by noticing, recording, and understanding patterns and by understanding our perspective and belonging within a larger system. Building telescopes and spectrometers to gather data is just one of the ways that humans have responded to that drive in more recent centuries.

8. Making Sense of Podcasts as a Class

14 MIN

Materials: *Making Sense of the Podcast Jigsaw*, sticky notes

Present **slide M**. Facilitate a Building Understandings Discussion by asking students to share some of the things they discussed in their groups. Ask each group to do or answer the following:

- *Share out the patterns your group recorded on sticky notes and then post them to the Patterns in the Sky poster.*
- *What did your group wonder about the phenomena in the podcast?*
- *Why was it important to the people you learned about to study the sky?*

Encourage students to draw on their responses to the questions on the slide (and on *Making Sense of the Podcast Jigsaw*) to answer this question.

Key Ideas

Purpose of the discussion: There are two goals of this discussion: (1) to generate ideas about why studying the sky is relevant for all people; and (2) to generate new ideas about specific patterns in the sky.

Listen for these ideas:

- People across time have been interested in the sky because patterns in the sky set the rhythms for life on Earth.
- Observing and keeping track of patterns in the sky can be useful and fulfilling (i.e., for making connections, maintaining power, navigating, farming, and maintaining a spiritual connection to the sky).

Other ideas to highlight if they come up:

- Stories and analogies related to the sky are legitimate ways to preserve knowledge about the stars and planets.
- A connection to the sky is a connection to the larger universe.
- Taking some perspective can help us better understand our own planet and our own problems.

Assessment Opportunity

Building towards: 1.B Obtain information from images, videos, and podcasts to describe patterns in natural phenomena of objects in the Solar System (and beyond), as seen from Earth.

What to look/listen for: Students should use the strategies and prompts on *Listening Group Roles Reference* to obtain and document information from the podcasts on *Making Sense of the Podcast Jigsaw* about the patterns

and phenomena described by each interviewee and the connections to the sky. Listen for students to refer to the phenomena from each podcast:

- Jess: when wombat season is and how what you see in the sky is connected to what you experience on Earth
- Thebe: viewing Selemela and the Southern Cross or the giraffe stars and making connections to people all over the world who have been collecting knowledge about the sky and testing their ideas to transmit information to the next generation
- Gerado: how using Sun and Moon based calendars allowed for rituals and gatherings to occur and mark the years
- Annette: how the Loon is visible all year round but the Great Panther constellation is not.

What to do: If students struggle to find the information they need in the reading, call attention to the strategies and prompts. Remind them to use the before, during, and after reading strategies from the close listening protocol on **slide K.** If students are struggling with listening to the podcast, allow students to read their assigned transcript with a partner.

9. Navigation and Exit Ticket

3 MIN

Materials: science notebook, blank piece of paper

Reflect on the podcasts individually. Present **slide N**. Ask students to respond to the personal reflection questions on the slide as an Exit Ticket. If there is time, ask for 2–3 volunteers to share something they wrote. Have students turn in their Exit Ticket as they leave class for the day.

Exit Ticket

- Are there any patterns or phenomena in the sky that you feel personally connected to? Explain your connection.
- How are your views about space and science similar to the views you heard about in the podcast? How are they different?
- Did listening to the podcast change any of your views about space and science? If so, how? If not, why not?



Forecast what comes next. Say, *Next time, let's spend some time making initial models and see if we can explain some of these patterns.*

End of day 2

10. Model patterns or phenomena in the sky individually.

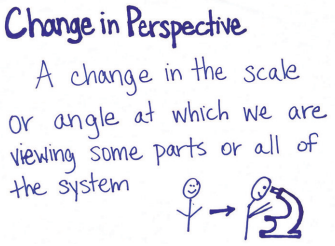
9 MIN

Materials: *My Initial Model to Explain:* _____, *Systems Modeling Scaffold* (optional), Patterns and Phenomena in the Sky poster

Orient students to where we have been and where we are going. Organize students into groups of 2–3 to prepare for this activity. Larger groups will increase the time you will need to spend. Display **slide O**. Point to the Patterns and Phenomena in the Sky poster. Say, *Wow, we have a lot of patterns and phenomena we are interested in. Choose a pattern or phenomenon that you want to explain today and share the pattern or phenomenon you chose with a partner.*

Give students a minute to do this and then say, *On Day 1 of this lesson, when we were talking about Manhattanhenge, we ended up identifying important parts and interactions we would need to include in a model to explain why we can see that phenomenon only on certain days of the year. We also realized when we were thinking about where to put the Sun on our map that it might make more sense to change where we are at when we look at the system in order to fully explain what is happening.*

First, consider the parts of the system for each phenomenon. Say, *Let's use that sort of thinking going forward. Consider first what parts and interactions you think you are going to need to include in your system diagram of the phenomenon or pattern you choose. Feel free to refer to the ones we outlined here for the Manhattanhenge phenomenon to decide which, if any, of these are also needed as well as what other parts or interactions you might also need to add. Tell your group what parts you think will need to be in the system you model to help explain your pattern.* Give students two minutes for this.



Model the system individually and then present to small groups. Display **slide P**. Review the directions on the slide. Emphasize that the shift in perspective called for on the handout is a way to get us to show the system from a different viewpoint, which can be a different angle and/or at a different scale. Add a similar co-constructed class definition to the Word Wall for **change in perspective:** A change in the scale or angle at which we are viewing some parts or all of parts of the system.**

Have each student choose one pattern that is listed on the Patterns and Phenomena in the Sky poster and individually develop and use a model to help explain it using *My Initial Model to Explain:* _____. Have students follow the directions on **slide P.** At this point, accept almost every idea students have. They will have more time in this unit to develop and revise their ideas.

*** Attending to Equity**

Supporting Emerging Multilingual Students: Provide opportunities for emerging multilingual students to break down the meaning of scientific words that are central to the lesson, such as *perspective*. *Perspective* might mean one thing to students in everyday talk that is slightly different from how we are using it here. Highlighting how words can have different meanings in different contexts can provide emerging multilingual students the chance and space in which to discuss any preconceptions about the meaning of the word(s) and to draw upon their personal experiences.

*** Supporting Students in Developing and Using Systems and System Models**

If needed, you could scaffold the idea of *perspective* further, by asking students to imagine what the Goldberg system might look like from another point of view, for example, that of the bird or that of the man. Consider using *Systems Modeling Scaffold* to lead a supplemental activity and discussion about this.

Note that the words *parts* and *components* are used interchangeably in the NGSS and in Using both words can be confusing for students, particularly emergent multilinguals, so be explicit when you use a synonym. Now might be a nice time to remind students that *parts* and *components* are different ways to refer to the things in a system that work together, but they can be used interchangeably.

11. Compare initial models.

6 MIN

Materials: *My Initial Model to Explain: _____*, *Systems Modeling Scaffold* (optional), Patterns and Phenomena in the Sky poster

Initial model sharing and revision. Then use **slide Q** to guide the following 2-step process:

- Each person gets two minutes to present their model.
- After this, they should go back and make any changes that they want to make to their model after hearing about other people's models.

Prepare for a gallery walk. Ask students to post their models on *My Initial Model to Explain: _____* around the room for a gallery walk. One way to do this is to tape the handouts to a wall. Another is to ask students to leave their notebooks open on the table to the page where they have pasted in the handout.

Additional Guidance

The sky is filled with phenomena, and our unit starts with a broad invitation to start with student connections and questions about any of the almost limitless celestial stories and models that they already have. Note that these models are not of just one system, pattern, or phenomenon but are of many different patterns in the sky, and it is okay that not all students will be modeling the same thing. This may be different from other units where all students were developing models in service of explaining a singular phenomenon. However, due to the vast scope and depth of the ESS-related DCIs in this Performance Expectation Bundle, there is not a single anchoring phenomenon that can drive the whole unit and student learning. By having students model different patterns and parts of a very large system (with many interacting subsystems), the unit will be able to add to and revise this consensus model at different points in the unit and make good on answering the majority of student questions about space. Thus increasing engagement and cultural relevance to students' lives and those in their community.

Though the unit is not driven by a single phenomenon, students will be making sense of a variety of investigative phenomena throughout the unit. Students will develop and revise models to explain investigative phenomena related to questions that developed from the anchor. In this way, the unit is still driven by student questions and making sense of phenomena. For example, in Lesson 2, students will investigate and add the Earth's axis being tilted toward the North Star, in Lesson 3 students will investigate and explain changes in the path and angle of the Sun from one year to the next and over thousands of years, in Lesson 4 they will revise their models to add that the angle of the Sun on Earth is responsible for the seasons, in Lesson 6 and 7 they will explain the current phase of the Moon the cyclic patterns of lunar phases, and a total solar eclipse. Lessons 8 through 11 will investigate why the color of the Sun changes at sunset, why the Moon changes color when it rises or sets and during a lunar eclipse, and why the sky is blue. Furthermore, in the final lesson set, students will expand their scale beyond the Earth–Sun–Moon system to answer their questions about the patterns apparent in the planets and stars and the role of gravity in causing those patterns.

12. Build a Consensus Model of systems in space.

25 MIN

Materials: *Initial Models Gallery Walk*, *Systems Modeling Scaffold* (optional), Initial Consensus Model chart, markers

Review models on a Gallery Walk. Display **slide R.** Distribute the *Initial Models Gallery Walk* handout. Have students move from model to model, recording on *Initial Models Gallery Walk* the similarities and differences that they notice. As students move around the room, take this time to look at some of the models and use them as a pre-assessment. Give them about five minutes. Then bring students back together in a Scientists Circle.

Assessment Opportunity

Building towards: 1.C Develop an initial model of systems in space to describe patterns we observe in the sky.

What to look/listen for: Look for students who are including parts or interactions in their system that might not be necessary to explain the pattern they chose. For example, a student might have chosen to model seasons but included all eight classical planets in orbit around the Sun in their model.

In addition, look for students who are representing scale in their models by indicating "zooming" of perspectives. This is a sophisticated way to represent scale and will become part of our consensus model later in the unit. Make note of these models to highlight in Lesson Set 4.

What to do: If students need support choosing what to put in their models, begin the Scientists Circle with a review of bounding systems. If most students are not modeling interactions, push students to think more about them (i.e., forces, sunlight, movement) among the parts as the class develops a consensus model. Make note of students who are representing interactions between parts and bring attention to their representations as the class builds their initial models.

Revisit classroom norms. Take this opportunity to remind the class how we listen to one another, press on one another's ideas, and ask questions of one another and that it's OK to disagree with ideas but it's important to be respectful. You can use **slide S** to remind students of the classroom norms (if you have developed your own set of norms, replace this slide with your norms).*

Remind students of the Communicating in Scientific Ways sentence starters.* Make certain a Communicating in Scientific Ways poster or handout is visible. Emphasize that each individual has contributions to make to their community of learners. Ask them which sentence starters they might want to use to help them talk to one another. Examples include these:

Think of an idea, claim, prediction, or model to explain your data and observations:

- My idea is ….
- I think that ….
- We could draw it this way … to show ....

Give evidence for your idea or claim:

- My evidence is ….
- The reason I think that this evidence supports this is ….

*** Attending to Equity**
Universal Design for Learning: Use classroom norms to support *engagement* by fostering an equitable learning community that promotes trusting and caring relationships. The norms should reinforce to students the value of: (1) the diversity of thought among all classroom community members in pushing our learning forward; and (2) providing a safe learning environment that ensures fair participation. In addition, classroom norms should interrupt cultural norms or stereotypes that could make science experiences feel uncomfortable for some students (e.g., as being someone who is not intelligent enough to think like a scientist, who cannot do the relevant math, who cannot share their thinking).

*** Attending to Equity**
Supporting Emerging Multilingual Students: Scaffolds such as sentence starters can model and facilitate particular oral or written language production skills, such as formulating questions, hypotheses, explanations, or arguments based on evidence (see Communicating in Scientific Ways poster). Such scaffolds may be of particular benefit for emerging multilingual students to help them develop

Other examples could come from: (1) listening to others' ideas and asking clarifying questions, (2) agreeing or disagreeing with others' ideas, and (3) adding to others' ideas.

Additional Guidance

Establishing norms is an important focus early in the school year. This brief reminder about norms assumes your classroom norms were already established in a previous unit. For more information about norms and how to establish them in your classroom, refer to the *Teacher Handbook*.

Use **slide T** to remind students that the goal of this Consensus Discussion is to determine areas of agreement and disagreement in our initial models to help us decide how to proceed in figuring out these patterns in the sky.

Scientists Circle



Students may be familiar with the Scientists Circle from the previous unit. Remind students of norms for participation and logistics of forming and breaking down the space. Include these important features:

- students sitting so they face one another to build a sense of shared mission and a community of learners working together;
- celebrating progress toward answering students' questions and developing more-complete explanations of phenomena; and
- focusing on where students need to go next and how they might select next steps in their work.

The class will be in a Scientists Circle all day, so there is no need to change chair arrangement between classes.

Ask each of the questions on **slide T** (and in *Initial Models Gallery Walk*).

- *What similarities did you see among parts of the systems? What about differences?*
- *What similarities did you see among the motions and interactions of objects? What about differences?*
- *What similarities did you see among perspectives? What about differences?*

Consider using a round-robin format to give every student a chance to either share something they wrote or comment respectfully on something someone else has shared. As students share out, use their ideas to draw an Initial Consensus Model for Explaining all of our different Phenomena and Patterns at the front of the room, as in the following descriptions and images.*

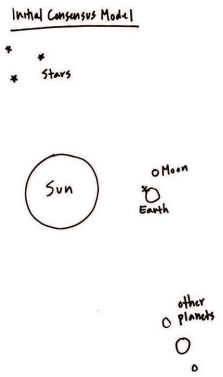
1. As students talk about parts of the system that they saw agreement on in the models, sketch and label them on chart paper at the front of the room. Follow students' directions on where you should place each part of the system they describe. Label the poster "Initial Consensus Model for Explaining All of Our Different Phenomena and Patterns." The first parts of the system that will be easiest to develop consensus on for every phenomenon will be: (1) a person, (2) the Earth, and (3) the person standing on the surface of Earth.



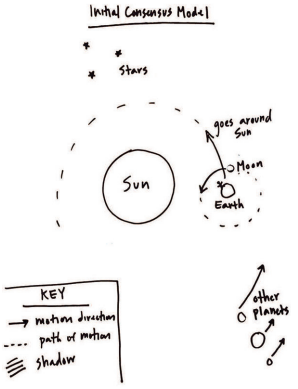
language skills to write or communicate their ideas to peers. It is important that scaffolds be used purposefully and removed when no longer needed.

*** Attending to Equity**
Universal Design for Learning: Use *representations* like color coding and/or letter or number coding to foreground parts of the model. Create a key to track what colors, symbols, or letter or number codes represent different parts of the system. While color coding is a useful way to quickly reference the parts of the model, letter or number coding helps ensure accessibility for any student who may be color blind. If color coding is used, consider a color palette that uses orange, blue, black, or dark brown.

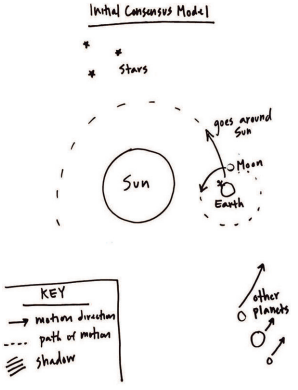
2. As students talk about additional parts of the system that they saw in the models, sketch and label them on chart paper at the front of the room. Emphasize that these parts may be needed for explaining some phenomenon or patterns, but maybe not others (e.g., stars). Follow students' directions on where you should place each part of the system they describe.



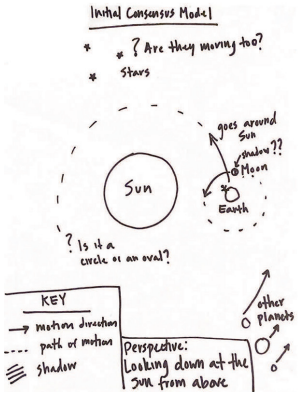
3. As students talk about changes or motions that they saw agreement on, ask them how they represented these. Students may suggest motions such as orbits or spin. Try to develop consensus on what they mean by both of these. Represent the orbit of the Earth around the Sun to account for a pattern they will claim the Earth goes through every year. Represent the spin of the Earth around its axis to account for a pattern they will claim the Earth goes through every day. These are two ideas that are already listed on the Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon from Day 1. Represent those now on the poster. It's OK if other movements (e.g., of the Moon) are not represented on the poster or are represented with a question mark to indicate that this is an area of uncertainty.



4. Students may suggest other interactions now to include in the model, such as energy transfer, paths of light, or forces such as gravity, contact forces, or magnetism. Students may suggest using arrows to show direction of movement. If there is something that students disagree about or something that a student suggests that was really only on a couple of models, you might add it to the poster but label it with a question mark. Remind students it is okay to disagree.



5. Look for students to notice that some of the models were drawn from a different perspective. Point this out if it doesn't come up naturally in what students see as similarities and differences. Ask, *Are all of these drawn from the same perspective?* Indicate perspective at the bottom of the model using words, for example, "Perspective: someone floating above the North Pole of Earth" or "Perspective: someone floating above the entire Solar System" or "Perspective: someone looking down on our town." Use the words that students use whenever possible. For example, if students are talking about "zooming out," use that phrasing instead of "floating."



Before beginning to gather student questions, take a few moments to check in on limitations of the Initial Consensus Model for Explaining All of Our Different Phenomena and Patterns. Say, *Let's take a moment to identify some possible limitations to our current model.* Accept all responses but listen for students to:

- Emphasize that in this system model we have developed a representation that shows some of the parts and changes in the parts of the system that are needed to explain many of the patterns we have identified, but this model still might not show the full set of interactions and perspectives we need to take in order to explain any one of the phenomena and patterns.
- Refer to Manhattanhenge as an example of where we would still have to figure out how to fit the map of New York into this system, as well as figure out how the direction of sunlight would be changing from one day to the next.
- Emphasize that this would be something that would be particularly challenging to do when we are constrained to showing something in 2D and that it might be easier to show in 3D, which is something we might want to try to do for many of these phenomena, but at least we've develop an initial map of many of the parts of the system and some of their changes and interactions we might need to consider in future investigations, explanations, and revisions to this model.

Additional Guidance

Indicate multiple scales only if several students draw different scales and point this out. It is unlikely that this will come out at this time, so don't force it. We will add multiple scales to our models in Lesson Set 4.

13. Navigation and Stop and Jot

5 MIN

Materials: science notebook

Pre-think questions with a Stop and Jot. Present **slide U**. Say, *Next time, we will build a Driving Question Board, or DQB. What questions do you have about some of the phenomena we have been talking about?* Have students write down some ideas in their notebooks. These will not be the questions that they put on the DQB but instead are a chance for students to begin the thinking they will have to do next time.*

End of day 3

*** Attending to Equity**

Universal Design for Learning: It is important to organize activities in ways that create opportunities to support student *engagement* in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). As students learn to go public with their ideas, it can help to give them time to think quietly and individually before having to go public with their questions in a small or large group. Do not bother to collect these Stop and Jots, but instead ask students to hold onto them to inform them of their work in the next class meeting.

14. Build the Driving Question Board (DQB).

27 MIN

Materials: science notebook, marker, sticky notes, DQB, markers

Orient students to where we have been and where we are going. Say, *We have been collecting experiences that help us understand how people are connected to patterns in the sky. Last time we were together, we modeled a system in space that can help us explain some of these patterns. Then we started thinking about the questions we have about this. Now that you've had time to think about it, let's start building our DQB.*

Write initial questions for the DQB. Make sure the Patterns in the Sky poster and the class's Initial Consensus Model poster are located at the front of the room where students can see them. Present **slide V**. Say, *We have been looking at phenomena and patterns in the sky and thinking about the space systems that produce them. What kinds of questions could we ask about these patterns and the systems that we think cause them that we could investigate as a class?* Look for students to suggest asking questions about what the pattern looks like, what causes the pattern, what the parts of the system are, what the interactions are in the system, how perspective makes a difference, and if the phenomenon or pattern is the same everywhere, among others.

Display **slide W**. Then, pass out 3–4 sticky notes and a marker to each student. Ask students to write one or two questions on the notes about patterns in the sky. They should record only one question per note. They should write their questions big and bold—we want to be able to see the questions clearly. To keep the focus on natural

phenomena rather than airplanes and UFOs, remind students to focus on patterns we see in the sky and that people have seen in the sky over millennia rather than singular events of artifacts of modern technology.

Here are some examples of the kinds of questions students might come up with:

- Why does the sky change into different colors while the Sun is setting?
- Why are stars more visible at nighttime?
- How far away are stars from Earth?
- Why do planets look bright when we see them at night?
- Why does the Moon turn red?
- Why does the Sun last longer in the summer than in the winter?
- Why does the Moon change shape?
- Do the stars orbit just like the Earth and Moon?
- How did people look at the stars and see figures? What causes constellations to appear in the sky?
- How big is the Solar System?
- How did everything form in the Solar System/universe?
- How would having multiple moons affect Earth?
- Why don't the planets orbiting the Sun get pulled in?
- What keeps everything in order?
- Why is it one season in one part of the world and another in another place?
- Why are the days different lengths during different seasons?

Additional Guidance

Students may have these kinds of questions: Why does the shape of the Moon change? What is an eclipse? How far away is the Sun? Is there a black hole in our Solar System? How big is the universe? Are there aliens? Why do stars move? What do the constellations mean? To keep the focus on natural phenomena rather than airplanes and UFOs, remind students to focus on patterns we see in the sky and that people have seen in the sky over millennia rather than singular events of artifacts of modern technology.

Gather in a Scientists Circle around the DQB. Instruct students to bring their sticky notes with completed questions along with their science notebooks to meet in a Scientists Circle around the DQB. The Initial Consensus Model poster and Phenomena and Patterns in Space poster should be visible.

Additional Guidance

The DQB will be central to the sensemaking that happens in the unit. There are a variety of ways to set up the DQB depending on your classroom resources, use of technology, and the number of students you see each day. What works for some will not work for others. Most important is that the DQB is visible to students each day and represents "our

shared mission." Students will be using the DQB to assess what they've figured out and identify next steps.

Remind students how to create the DQB (use **slide X** if needed):

- The first student reads their question aloud to the class then posts it on the DQB.
- Students who are listening should raise their hand if one of their questions relates to the question that was just read aloud.
- The first student selects the next student whose hand is raised.
- The second student reads their question, says why or how it relates, and posts it near the question it most relates to on the DQB.
- That student selects the next student, who may have a related question or a new question.
- We will continue until everyone has at least one question on the DQB.

Organize questions into categories. As students share, questions will naturally cluster into similar areas, such as questions about the Sun and questions about the Moon. Once students have finished their sharing, ask students to look at the questions for any additional organization that can be done. Use larger stickies to label these clusters. Some clusters that may emerge include: "Stars," "Moon," "Sun," "Planets," and "Other."



Additional Guidance

Note that, at this time, students may have a lot of questions about the color of different objects in the sky/space. At this time, leave those color questions clustered with the object they focus on. For example, Why is the Moon red sometimes? would be clustered with other Moon questions instead of in a standalone color cluster (unless a student asks explicitly to make a cluster around color). In Lesson 8, students will return to the DQB with a greater focus on color.

Develop an initial driving question. Say, *Now that we have written our questions, what question should we put at the top of our DQB?*

Look for students to suggest something like these examples:

- *How are we connected to space through patterns in the sky?*
- *Why do we see patterns in the way things look in the sky?*
- *How do things in space create the patterns we see in the sky?*

Push students to suggest questions that address:

- patterns (or phenomena or things that happen),
- our experience of those patterns (our connection, that we see them), and
- perhaps even causal mechanisms for those patterns (why do they happen? why do we see them?).

Feel free to suggest tweaks to students' wording or combine multiple questions. For example, if one student suggests, "Why are there patterns in the sky?" and another student suggests, "What does the Solar System look like?" you can say, *I heard one person asking about patterns and one person asking about systems in space. Can someone combine these into a single question?* Once an idea is on the table that meets the criteria and/or looks like one of the previous examples, revoice this question. Then ask, *Does everyone agree on this for our initial driving question?* Once the class agrees, add the question to the top of the DQB.

Assessment Opportunity

Building towards: 1.A Ask questions about systems in space that arise from observations of patterns in the sky.

What to look/listen for: As the class builds the Driving Question Board (DQB), listen for: (1) the subsystems, patterns, and changes in objects that students are asking questions about; and (2) how the questions relate to patterns and systems. Possible systems/subsystems could include the Earth–Sun, Earth–Moon, Earth–Sun–Moon, the Solar System, color changes of objects such as planets/moons/suns/stars/galaxies, shape changes (or eclipses/transits) of solar system objects, orbits, comets, etc.

What to do: It is important that *all* questions posed by students be placed on the DQB regardless of whether they are open-ended or close-ended. As students ask questions, have them reflect on any patterns that have few or no questions posted on the DQB. Prompt students to generate more questions in this space so that we are motivated to investigate several subsystems of the Solar System. If students are struggling to come up with questions, have them look back through their science notebook, at the posters created during this lesson, at the podcasts, and at the stories from their community. Ask, what personal experience have you had viewing objects and their patterns in the sky? What was interesting or confusing about what you saw, and why you were able to see it? Give students time to go back and revise their sticky notes or create new sticky notes. If you notice this is occurring for several students, have them come together in a Turn and Talk, share their questions (or parts of questions) with their partners, and follow which objects or part of the system their question comes from.

15. Brainstorm next steps. 13 MIN

Materials: science notebook, Ideas for Future Investigations and Data We Need chart, markers

Develop ideas for investigations and data we need. Present **slide Y**. Ask, *In order to start answering some of these questions, what investigations could we do and what data do we need?* Give students a couple of minutes to jot down ideas in their notebook (as directed by the slide) before eliciting ideas. Students may suggest things like these:

- naked-eye images of objects in the sky (such as the Moon or planets over time)
- size and distance of objects in the universe
- up-close photos of the Moon, Sun, or planets through a telescope
- dates of comets, eclipses, and other events
- modeling with spheres and lights
- make observations of the sky ourselves (If this doesn't come up, ask students what we could do to provide data about how the Moon changes or where the Sun moves or some other pattern that has been identified.)
- using computer simulations

Make a public record of our ideas. Keep a record of these ideas at the front of the room on chart paper. Label this poster "Ideas for Future Investigations and Data We Need."

16. Navigation and Optional Home Learning

5 MIN

Materials: *Lesson 1 Community Guide for Looking at the Sky*

Consider where to go next. Present **slide Z** and say, *We had the idea of actually going outside and observing these patterns in the sky and also gathering more stories of connections to the sky from communities all over the world. Let's do that, whenever we can! How can we gather these stories and patterns from observations in our own communities and from other cultures or places?*

Listen for students to suggest some of the following ideas; if they're not already on your class list of ideas for investigations and data we need, you can add them now:

- going outside and looking at the sky with members of our community
- listening to people from around the world
- watching videos of phenomena/patterns in the sky from other communities

Say, *That sounds great! I encourage you to safely begin noticing what they see in the sky, keeping notes, and collecting stories from their communities*. Distribute the *Lesson 1 Community Guide for Looking at the Sky* as a tool to support students in talking with other people they trust to begin making observations of changing patterns in the sky.

Ask, *What objects in the sky should we start looking at?* Listen for students to mention that we can see the sun almost every day. If students do not mention beginning by looking at patterns of the Sun, ask, *If we are feeling stuck, what objects might we want to see first to explain the phenomena or patterns from Manhattanhenge or the podcasts?*

Safety Precautions

If you feel it is not safe or practical for students to be outside of their homes, especially at night, encourage students to look out a window or have them do the activity at school. Also, make sure to reiterate with your students to never stare directly at the Sun because it can be permanently damaging to their eyes.



Additional Guidance

Lesson 1 Community Guide for Looking at the Sky is a tool that will be used in several lessons to help support students and trusted members of their community in observing specific patterns in the sky. Encourage students to bring those observations and ideas back to class to inform and enrich upcoming work in the classroom. Inviting students to bring their family and/or community knowledge, experiences, and practices into school not only supports students in coordinating the learning they do outside school with what they do in school, but can also help you as a teacher to expand your understanding of the strengths of the families and communities you work with. Do not require that students complete this home learning and do not score it; the goal of this guide is to promote conversation between students and others in their family and/or community about what they're doing in class, and expand students' exploration of patterns in the sky by bringing in those ideas.

ADDITIONAL LESSON 1 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1 Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 8 topics, texts, and issues, building on others' ideas and expressing their own clearly.

CCSS.ELA-LITERACY.SL.8.1.B Follow rules for collegial discussions and decision-making, track progress toward specific goals and deadlines, and define individual roles as needed.

When students work in small groups to listen to podcasts, they each take different roles to help their group function productively. The roles suggested on *Listening Group Roles Reference* support students in sharing the cognitive load of analyzing and interpreting the podcasts rather than being simply procedural. The suggested questions and comments provided for each role support students as they become more independent in navigating group decision-making, coming to consensus, and tracking their progress on the task at hand.

CCSS.ELA-LITERACY.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. Students obtain information from podcasts (with accompanying images and transcripts) from cultural astronomers sharing stories about phenomena in the sky. When discussing the podcasts in their small groups, students consider the title of each podcast and how it fits the content, which requires them to consider the central ideas in that podcast. When sharing about the podcasts with the whole class, students summarize how people observe the sky, what patterns they've seen, and how they use those observations. For some students, the ways people in the podcasts interact with the sky is different from their own experiences, so they will have to consider without bias or judgement that stories and analogies related to the sky are legitimate ways to preserve knowledge about the stars and planets.

LESSON 2

What patterns are happening in the sky that I have experienced and can observe (through models and tools)?

Previous Lesson

We analyzed how the Sun aligned with structures and developed an initial model. We considered how the position of the sunset on Earth can connect our daily lives to the sky, and we brainstormed patterns in the sky. We listened to podcasts about connections to the sky and identified additional patterns. We developed a model of the parts and changes in the system needed to explain many patterns. We developed questions for the DQB and brainstormed ideas for where to go next.

This Lesson

Investigation

1 DAY



Stellarium

We gather information from videos about Native American stories about a star that does not move in the night sky. We share our experiences about noticing this star, sometimes called the North Star. We analyze data (from a video of a simulation or from a simulation) of the sky during the day and night over the course of 6 months of the day and night. We share the repeated patterns and changes that we observe in the sky. We add our wonderings to the DQB. Finally, we develop initial models to explain why the North Star does not appear to move in the night sky. We are still wondering what causes the amount of daylight changes during the year, so we decide to investigate that next.

Next Lesson

We will watch a video of the simulated motion of the Sun through the sky over a day for different parts of the year. We will create physical models to see if our understanding is correct. We will revise our drawn models to show the changed location of Polaris and Earth's tilted axis.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

2.A Use a graphical display (a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in location of sunrise/moonrise and sunset/moonset, the paths of motion of the sun and moon, and and how most stars move and which one doesn't in the sky at night) in a large data set (across 6 months from a specific location on earth's surface).

What Students Will Figure Out

- In the Northern Hemisphere, Earth's northern axis is always pointed toward the North Star, which explains why it does not appear to move in the night sky.

- The Sun and Moon appear to rise in the eastern sky, move across the sky from east to west, and set in the west.
- The stars visible in the night sky in the Northern Hemisphere appear to move counterclockwise in a circular path around the North Star. This is because the Earth spins counterclockwise on its axis when looking down on it from above its North Pole.

Lesson 2 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	4 min	**NAVIGATION** Ask students to share what they noticed in the night sky. Introduce new stories about the night sky.	A	
2	12 min	**WATCH VIDEOS OF NATIVE AMERICAN SKY STORIES** Watch two videos of different Native American sky stories explaining why the North Star does not move.	B-E	8.4 Lesson 2 Navajo Story of the Stars (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 2 Paiute Star Stories (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	15 min	**EXAMINE VIDEO OF THE SKY** Watch a video of the sky made with a computer simulation to notice patterns in movement of objects in the day and night sky.	F-H	sticky notes, markers, 8.4 Lesson 2 Observing the Sky (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Patterns in the Sky poster, DQB
4	10 min	**DEVELOP MODEL OF PATTERNS IN THE SKY AND NAVIGATION** Develop an initial model to explain the patterns of motion observed in the sky video.	I-K	*A Model to Explain the Movements of Objects in the Sky*, Model Components and Their Movements in the Sky poster
5	4 min	**NAVIGATE TO THE NEXT LESSON** Develop an initial model to explain the patterns of motion observed in the sky video.	K	Model Components and Their Movements in the Sky poster

End of day 1

Lesson 2 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • sticky notes • markers • *A Model to Explain the Movements of Objects in the Sky*		• 8.4 Lesson 2 Navajo Story of the Stars (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 2 Paiute Star Stories (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 2 Observing the Sky (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Patterns in the Sky poster • DQB • Model Components and Their Movements in the Sky poster

Materials preparation (10 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the videos

- Navajo: Story of the Stars 8.4 Lesson 2 Navajo Story of the Stars (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Paiute: Star Stories 8.4 Lesson 2 Paiute Star Stories (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- Observing the Sky 8.4 Lesson 2 Observing the Sky (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Make sure the Patterns in the Sky poster that the class made in Lesson 1 is posted and visible for all students and that the DQB is accessible. In addition, prepare a new poster on a piece of chart paper titled, Model Components and Their Movements in the Sky.

Write the following on 4 separate pieces of paper:

- E = east
- W = west
- N = north
- S = south

Tape these to the corresponding walls of your classroom to help students orient to these directions for this lesson and future lessons.

Lesson 2 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will use a video developed with planetarium software to observe the motion of objects through the sky. This entry point into thinking about seasonal patterns builds on first grade standards about the number of hours of daylight at different times of the year (1-ESS1-2) and the fifth grade standards for explaining day and night using a model of the Sun and Earth and the rotation of Earth around it axis (5-ESS1-2). Students use these observations to build an understanding of how Earth's spin on its axis and orientation explains the movements of objects in the sky.

Where We Are NOT Going

We do not develop a model to account for Earth's tilt on its axis. This will be developed in the next lesson and used to account for changes in the amount of daylight and angle of insolation. We also do not identify what controls the motion of objects in the sky or how they were formed. In the fourth lesson set of the unit, students explore gravity and its influence on objects in the sky and the formation of the Solar System. It is not until that point that we will define, as a class, what we mean by the Solar System.

LEARNING PLAN FOR LESSON 2

1. Navigation

4 MIN

Materials: None

Additional Guidance

Connections to Me and My Community

In Lesson 1, students considered how changes in the length of a day impact their experience. In this lesson, students get an opportunity to connect their experiences to stories from Native American communities.

Review the front matter for this unit for an overview of how this unit is designed to help students see why the patterns in the sky are relevant to their lives, their communities, and life on Earth.

Orient students to where we have been. Present **slide A**. Say, *Last time we were together, we met with a trusted member of our community to examine patterns in the sky using Lesson 1 Community Guide for Looking at the Sky. What were some of the things you observed in the sky that we were interested in observing to figure out more about some of these patterns? Turn and talk with a partner.**

Solicit student ideas. Listen for students to talk about the Sun, the Moon, planets, and so forth.*

Then say, *I found a few more stories about some cultures that paid attention to the sky because it helped to shape their lives. Let's see if we can connect the stories we heard in our last class and the ones we will be hearing today to some observations we have seen.*

*** Attending to Equity**

Supporting Emergent Multilingual Students: It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to emergent multilingual students. Partner or small-group talk should precede whole-group discussion whenever possible to give students an opportunity to share their ideas with one or two peers before going public with the whole class.

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Encourage students to use both everyday and scientific vocabulary to consider scale by asking questions to probe their ideas. For example, if a student says that something happens really fast, say, *"Really fast" might mean something different at different time scales. When you say "really fast," do you mean in a couple of seconds? In an hour? Over a year? A year might seem long to us, but in the life of Earth, remember, that is pretty fast.*

2. Watch videos of Native American sky stories. 12 MIN

Materials: science notebook, 8.4 Lesson 2 Navajo Story of the Stars (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 2 Paiute Star Stories (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Introduce the first Native American sky story. Display **slide B** and have students create a Notice and Wonder chart in their science notebooks. Play Navajo: Story of the Stars 8.4 Lesson 2 Navajo Story of the Stars (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Point out the map of Native American tribes. Say, *I have another video to show you from a different Native American tribe. We will share what we noticed and wondered from the Navajo Nation story after watching the Paiute (PY-yoot) story.*

Display **slide C** and have students add another Notice and Wonder chart to their science notebooks. Play Paiute: Star Stories 8.4 Lesson 2 Paiute Star Stories (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Discuss similarities and differences between the stories. Display **slide D** and have students turn and talk with a partner for a few minutes about the similarities and differences between the two sky stories.

Suggested prompts	Sample student responses
What similarities did you notice in each of the two Native American sky stories?	*They both described a star that did not move in the night sky during the year.* *They noticed a star that did not move.* *Both use stars symbols on things they use, like trays.*
What differences did you notice in each of the two Native American sky stories?	*The reasons for why the star did not move were different.* *In the Paiute story, a mountain goat was stuck at the top of a mountain and became the North Star.* *In the Navajo story, the North Star is a fire hearth that the male and female revolvers move around during the year.* *The Navajo talk about how constellations govern their lives.*

Share prior experiences. Display **slide E**. Ask students,

- *Have you heard of or seen the North Star? (Accept all answers.)*
- *What other things have you noticed in the sky that don't move? Are there other things? (Accept all answers.)*

3. Examine video of the sky.

15 MIN

Materials: science notebook, sticky notes, markers, 8.4 Lesson 2 Observing the Sky (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Patterns in the Sky poster, DQB

Watch a video to observe patterns in the sky. Display **slide F**. Say, *Since some of the patterns we've heard about happen over longer periods of time, I have a video made with computer software that will allow us to see these patterns in a shorter amount of time. As you watch the video, record what you notice and wonder in your science notebooks.** Play Observing the Sky 8.4 Lesson 2 Observing the Sky (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Additional Guidance

The video is separated into two parts; January through June and July through December using two different points of view. Each portion will take around 9 minutes to watch. Consider separating the class into two groups to watch each portion of the video.

Alternate Activity

Instead of showing the video created with Stellarium software, you can demonstrate it using your desktop or have students download the software onto their devices to run the simulation. For more information, see *Stellarium Introduction Teacher Reference*.

Identify patterns from the video. Have students get into groups of 3 to 4.* Display **slide G**. Instruct groups to share their noticings with each other and identify patterns and non-patterns of objects in the sky.* Allow groups some time to identify patterns and record them on sticky notes.

Have the Patterns in the Sky poster displayed so that groups can add their patterns.* As students describe the patterns, ask all students in the class to reenact any direction-related patterns by pointing with their arms to the corresponding wall in the room, labeled with E, W, N, or S.

Suggested prompts	Sample student responses
What patterns did your group notice while observing the video of the sky?	*The Sun moves from east to west.* *The Moon moves from east to west.* *Stars move in a circular path around a central point.* *The length of day and night changes.* *Some groups of stars are only visible during certain times.*
Were there any objects that did not follow a pattern or that didn't appear to move?	*All of the stars but one moved in the night sky.*

*** Supporting Students in Engaging in Analyzing and Interpreting Data**

Students might not include enough details when recording data and observations. You can encourage them to do so by asking questions like, *I noticed you identified that the Sun is moving in the sky. Can you be more descriptive? We want to try to be able to build an idea of how specific objects appear to move.* Or, *Do they all move in the same direction? I notice you wrote down the objects are all moving. Are all of these objects in the sky moving in the same way?* By doing this, students can understand how being specific in descriptions and observations will make it easier when they analyze and interpret the data to find similarities and differences and will result in the collected data serving as stronger evidence.

*** Attending to Equity**

Supporting Emergent Multilingual Students:
Depending on the lesson goal, it can be helpful to intentionally group emerging multilingual students with certain peers. Sometimes this could be peers who know the same languages as them, while other times it could be peers whose English language development is slightly more advanced. It is important that this

Suggested prompts	Sample student responses
Where was that star that appeared to never move located in the sky?	*The star that did not move was due north.*
How do our observations compare with the observations from other civilizations we have heard?	*They match up, like the two Native American stories talked about a star that does not move and that it was north.* *We also heard about how certain constellations are in the sky during certain times of the year. We saw those patterns too!*

Add new questions to the DQB. Display **slide H** and have students individually add more questions to the DQB.* Say, *Use the wonderings you had while watching the videos in class today to help create more questions to add to our DQB.* Allow students a few minutes to record questions on sticky notes before moving into a Scientists Circle.

Look for students to add questions like these examples:

- *Why does the Moon seem to follow a similar path as the Sun?*
- *Why does the Moon seem to move a little slower than the Sun?*
- *Why do the stars move differently from the Sun or Moon?*
- *Why is only one star not moving?*

grouping be thoughtful and that it varies throughout the course of a unit so that students benefit from working with different peers.

*** Supporting Students in Developing and Using Patterns**
Remind students that we are seeing a pattern when we observe something repeat, such as an event, the shape of something, or the color of something. Noticing patterns is often a first step to organizing phenomena and asking scientific questions about why and how the patterns occur.

*** Attending to Equity**
Universal Design for Learning: Allowing students to use actions and multiple modalities to *express* their ideas supports student ownership of their learning by giving students choice, access, and control in navigating their own understanding around the science ideas.

*** Attending to Equity**
A Driving Question Board (DQB) provides a public representation of the class's joint mission. Students can share their questions and wonderings with one another, and the visual representation offers another modality for students to access science in the classroom.

4. Develop model of patterns in the sky and navigation. 10 MIN

Materials: science notebook, *A Model to Explain the Movements of Objects in the Sky*, Model Components and Their Movements in the Sky poster

Lead a building understanding discussion.* Display **slide I**.

Additional Guidance

Prior Knowledge: Students may know, from 5th grade, the movements of the Earth, Sun, and Moon and how these movements help describe the different positions of the Sun, Moon, and stars throughout the year. This lesson builds on that knowledge that the Earth is spinning but adds the idea that the Earth's axis is pointed toward a single star, Polaris, explaining why that lone star does not appear to move through the night, on any night of the year, and all the other stars visible in the sky (in the N. Hemisphere) appear to spin around it.

Suggested prompts	Sample student responses
What do the patterns we identified from observing the sky help us determine about the interactions of the Earth and Sun?	*The Earth spins the same way each day, so it must be spinning so that the Sun moves from east to west.*
What do the patterns we identified from observing the sky help us determine about the interactions of the Earth and Moon?	*I think the reason the Moon moves the same way across the sky, with the Sun, is because of how the Earth spins on its axis.*
What do the patterns we identified from observing the sky help us determine about the interactions of the Earth and North Star?	*If the North Star isn't moving in the sky, that means it must line up with something on Earth.* *I think the reason the North Star doesn't move is because we are pointed toward it.* *Earth's axis must be pointed toward it, because everything else but that moves in the sky.*
What do the patterns we identified from observing the sky help us determine about the interactions of the Earth and other stars?	*The other stars in the sky move around the North Star in a circle.*
How would you describe the way they moved in a circle? Was it the way the hand of a clock moved around the center of it (clockwise) or was it the opposite direction (counter clockwise)?	*I didn't pay attention to which way the circle moved.* *Everything was moving counterclockwise!*

*** Strategies for This Building Understandings Discussion**

A Building Understandings Discussion is a useful kind of discussion following an investigation because the purpose is to focus students on drawing conclusions based on evidence. Your role during the discussion is to invite students to share conclusions and claims and to push them to support their conclusions and claims with evidence. Students can disagree with each other, and the class does not need to reach consensus on all ideas shared, but rather areas of disagreement can motivate future investigations. Helpful prompts during these kind of discussions include:

- What can we conclude?
- How did you arrive at that conclusion?
- What evidence led you to this conclusion?

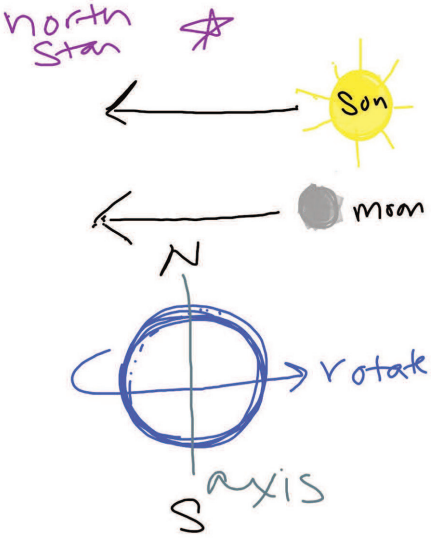
*** Supporting Students in Engaging in Developing and Using Models**

Emphasize to students that they will use models for a purpose. Models are dynamic and can change as new information is learned, and models need to be "applied" to explain a phenomenon, design a solution, or make a prediction about either of these to be useful. Models are not used to only describe something or

Develop initial models to explain patterns of movement of objects in the sky.* Display **slide J**. Record the objects and their movements suggested by students on the Model Components and Their Movements in the Sky poster.

show what is happening, but rather, students should learn to use them to show how or why something happens—to develop an explanation.

Suggested prompts	Sample student responses
Before you try to create a model to help explain why these objects appear to move the way they do, let's take stock of what objects we should include in our models.	*Earth* *Sun* *Moon* *North Star*
What movements should we include in our models?	*The Earth is spinning on its axis.* *The direction the Sun and Moon (appear to) move across the sky.* *The North Star does not move.* *The direction the other stars (appear to) move across the sky.*
What else are we going to need to show in the model to help us understand why a person where we live would see these apparent movements of these objects across a day and night?	*a person* *a person standing in the Northern Hemisphere*



Handout *A Model to Explain the Movements of Objects in the Sky* and give students a few minutes to create initial models. If you do not have enough time, this can be completed as home learning.

Collect the initial models on *A Model to Explain the Movements of Objects in the Sky* from students as a formative assessment opportunity. A sample initial model is shown in the following image.

Assessment Opportunity

Building towards: 2.A Use a graphical display (a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in location of sunrise/moonrise and sunset/moonset, the paths of motion of the sun and moon, and and how most stars move and which one doesn't in the sky at night) in a large data set (across 6 months from a specific location on Earth's surface).

What to look/listen for: Student models should incorporate data (temporal and spatial relationships) from the Observing the Sky video to determine that the patterns of movement of objects in the sky is due to Earth's spin on its axis. One object, the North Star, does not appear to move in the sky because Earth's axis is pointed toward it. Look for the following:

- The Earth's axis points toward the North Star.
- A person standing on the surface of the Earth in the Northern Hemisphere.

- Other stars above the Northern Hemisphere of the Earth.
- The Earth spins on its axis counterclockwise.
- The Sun and Moon move across the sky from east to west.
- The North Star does not appear to move because Earth's axis is pointed toward it.

What to do: Use your review of student initial models to make sure they use data as evidence to support that Earth's axis is pointed toward the North Star. This understanding is the key one for them to have at this point in the unit, before moving on to the next year. If students are missing this understanding, ask them, *What would explain why the North Star doesn't appear to move in the sky, but all other stars, including our Sun, do appear to move?* Have students revisit the patterns and non-patterns they identified earlier in the lesson to provide evidence for their thinking.

5. Navigate to the next lesson.

4 MIN

Materials: science notebook, Model Components and Their Movements in the Sky poster

Reference an unaccounted for solar pattern over a longer timescale. Say, *The models you developed are trying to account for the patterns of motion for many objects in the sky over the course of one day and one night. But we also noticed some patterns from the video and our lives that occur over the course of a year. One of those was that the amount of sunlight changes throughout the year. How could we use or revise our model to help explain why this is? What do you think causes this?* Accept all ideas. Display **slide K** and discuss the related questions as a class.

Suggested prompts	Sample student responses
If we wanted to explain patterns that occur over the course of a year (e.g., changes in the amount of sunlight each day), what are some possible advantages in developing a 3D model of the system?	*It will be easier to represent movement.* *There will be more movement we have to represent for showing changes over the course of a year.* *It will be easier to understand the perspective of the person on Earth in the system over time.*
What are some possible disadvantages or limitations you think we may encounter with such a model?	*It could be harder to keep all the objects oriented to each other in a particular way (e.g., we only have two hands each).* *It may be harder to represent things like the direction the light is coming from to the person seeing it.*

Say, *Next class, we will explore this further and see what we figure out and what limitations we encounter when trying to develop a three-dimensional model of the objects in this system that you drew today to explain why the changes we observed in sunlight over the course of a year happen.*

LESSON 3

How can we explain the Sun's path change over time?

Previous Lesson

We gathered information about Native American stories of the night sky and shared our related experiences. We analyze data (from a video of a simulation or from a simulation) of the sky during the day and night over the course of 6 months. We shared our noticings and added our wonderings to the DQB. We used our new information to develop initial models. We still wondered about what causes the amount of daylight to change during the year, so we decided to investigate that next.

This Lesson

Investigation

3 DAYS



We watch a video of the simulated motion of the Sun through the sky over a day for different parts of the year. We notice that in summer the apparent path of the Sun in the sky is higher and daytime is longer. We create physical models to see if our understanding about why this is happening is correct. Our physical models cannot account for the differences in the length of daylight over a year. We revise our model of the system in small groups to try to account for changes in the amount of daylight. We figure out that Polaris is not directly north above Earth, but it is slightly off of north, resulting in Earth's axis being tilted toward it, which explains the changes in daylight during the year. We revise our drawn models to show the changed location of Polaris and Earth's tilted axis. We wonder what other phenomena can be explained by Earth's tilt and decide to study that next.

Next Lesson

We will analyze seasonal temperature data from two cities in the United States and develop a physical model to collect and analyze data on changes of sunlight energy on Earth's surface as a result of changes in solar elevation. We will develop a Gotta-Have-It Checklist and complete an assessment applying our models to another location on Earth.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

3.A Use a graphical display (simulated motion from a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in solar elevation and length of day) in a large data set (across 6 months from a specific location on earth's surfaces).

3.B Collect and produce data showing patterns of changes in daylight and the angle of elevation of the Sun in the sky to serve as evidence to evaluate the accuracy of an initial physical Earth–Sun System model.

3.C Revise a model of the patterns of movement of the Earth around the Sun to explain that changes in the amount of sunlight and angle of elevation of the Sun in the sky during the year is due to Earth's axis being tilted toward Polaris.

What Students Will Figure Out

- Changes in the length of a day and angle of elevation of the Sun in the sky occur in a regular, repetitive, and cyclical pattern.
- Earth's axis is tilted at an angle and is pointed in the Northern Hemisphere towards Polaris, called the "North Star".
- As the Earth orbits around the Sun and is tilted on its axis, we observe changes in the amount of daylight and how high the Sun is in the sky over the course of the year.

Lesson 3 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Brainstorm a list of activities that happen as the amount of sunlight changes. Introduce the planetarium software.	A	
2	5 min	**MAKE PREDICTIONS ABOUT THE SUN** Make predictions about what we will see the Sun do when we watch the video of the planetarium software.	B-C	
3	20 min	**OBSERVE THE SUN WITH PLANETARIUM SOFTWARE** Use a video made with planetarium software to make and record observations of the Sun over the course of a year.	D-F	*Observations of the Sun: Location* _____, computer, 8.4 Lesson 3 Measuring the Sun: January - March (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: April - June (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: July - September (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: October - December (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Sun Measurement Orientation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), "Changes in sunlight and angle of the Sun in the sky over one year" poster

Part	Duration	Summary	Slide	Materials
4	17 min	**INITIAL IDEAS AND NAVIGATION** Share initial ideas if the patterns of the Sun in the sky have happened over hundreds of years.	G-I	*Sun Patterns Over Many Hundreds of Years*, computer, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
				End of day 1
5	2 min	**NAVIGATION** Remind students of where we left off yesterday. Prepare to share data.		*Sun Patterns Over Many Hundreds of Years*
6	15 min	**BUILDING UNDERSTANDINGS DISCUSSION** Share group data and identify patterns to analyze changes in the amount of sunlight and the angle of the Sun over hundreds of years.	J-K	*Sun Patterns Over Many Hundreds of Years*, "Changes in sunlight and angle of the Sun in the sky over hundreds of years" poster
7	10 min	**PROCESS PATTERNS OF THE SUN IN THE SKY** Connect patterns of the Sun in the sky from our recorded data to the patterns identified by other civilizations in earlier lessons.	L-M	*A Model to Explain the Movements of Objects in the Sky*, "Patterns from the Sky" poster from Lesson 1
8	15 min	**INITIAL CLASS PHYSICAL MODEL OF EARTH–SUN SYSTEM** Model the system for students physically at the front of the room. Record the parts and interactions in a model map.	N-Q	Earth–Sun Modeling Demonstration
9	3 min	**NAVIGATION** Problematize differences in the physical model data and NOAA data.	R	*Sun Patterns Over Many Hundreds of Years*, *Mapping the Model to the Earth–Sun System* (optional)
				End of day 2
10	5 min	**NAVIGATION** Remind students that the data from our physical models did not match the data we recorded from the NOAA websites.	S	
11	10 min	**(PHYSICALLY) REVISE THE MODEL OF THE EARTH–SUN SYSTEM** Revise the model of the Earth–Sun system using physical objects to better reflect the data we recorded from the NOAA websites.	T	*Sun Patterns Over Many Hundreds of Years*, *Modeling the Earth–Sun System*, *Mapping the Model to the Earth–Sun System* (optional), chart paper, markers, Physically Modeling the Earth–Sun System
12	13 min	**BUILDING UNDERSTANDINGS DISCUSSION** Build understanding that in order to explain changes in sunlight and the angle of the Sun in the sky over the course of a year, the Earth's axis must be tilted toward Polaris.	U-V	*Sun Patterns Over Many Hundreds of Years*, *Modeling the Earth–Sun System*

Part	Duration	Summary	Slide	Materials
13	10 min	**UPDATE PROGRESS TRACKERS** Update Progress Trackers to reflect new understandings.	W	
14	5 min	**NAVIGATION** Make connections to why Earth's tilt matters to students. Brainstorm other phenomena that are associated with Earth's tilt.	X	"Activities that happen when the amount of sunlight changes" poster

End of day 3

Lesson 3 • Materials List

	per student	per group	per class
Earth–Sun Modeling Demonstration materials	• *Mapping the Model to the Earth–Sun System* (optional) • safety goggles		• 1 4-inch sphere • 4 push pins • 1 round push pin • 1 fabric tape measure • 1 ruler • 1 twist-tie • 1 rubber band • 1 60W light bulb • 1 bulb socket • 1 extension cord • 1 plastic coffee stirrer • 1 plastic clamp • 1 Sharpie marker • 12 inches of 12 gauge aluminum wire • masking tape to secure lamp to table (optional)

	per student	per group	per class
Physically Modeling the Earth–Sun System materials	• *Modeling the Earth–Sun System* • safety goggles	• 1 4-inch sphere • 2 push pins • 1 round push pin • 1 rubber band • 1 60W light bulb • 1 bulb socket • 1 extension cord with power strip • 1 plastic clamp • 1 fabric tape measure • 1 ruler • 1 twist-tie • 1 Sharpie marker • 12 inches of wire • 1 plastic coffee stirrer	
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Observations of the Sun: Location* _____ • *Sun Patterns Over Many Hundreds of Years* • science notebook • *A Model to Explain the Movements of Objects in the Sky* • *Mapping the Model to the Earth–Sun System* (optional) • *Modeling the Earth–Sun System*	• computer • 8.4 Lesson 3 Measuring the Sun: January - March (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 3 Measuring the Sun: April - June (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 3 Measuring the Sun: July - September (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 3 Measuring the Sun: October - December (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)	• 8.4 Lesson 3 Sun Measurement Orientation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • "Changes in sunlight and angle of the Sun in the sky over one year" poster • computer • (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • "Changes in sunlight and angle of the Sun in the sky over hundreds of years" poster • "Patterns from the Sky" poster from Lesson 1 • chart paper • markers • "Activities that happen when the amount of sunlight changes" poster

Materials preparation (60-90 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure the Patterns in the Sky poster that the class made in Lesson 1 is posted and visible for all students and that the DQB is accessible. Prepare chart paper for new posters. These are the posters you will make in this lesson:

- Activities that happen when the amount of sunlight changes
- Changes in sunlight and the angle of the Sun in the sky over one year
- Changes in sunlight and angle of the Sun in the sky over hundreds of years

For the "Changes in sunlight and the angle of the Sun in the sky over one year," you will need to draw a three-column chart. Label the left column of the chart with each month of the year, the middle column with "Amount of sunlight," and the right column with "Angle of the Sun in the sky." For the "Changes in sunlight and angle of the Sun in the sky over hundreds of years," you will need to create four, three-column charts, one for each of the following years: 1,000, 1,500, 2,000, and 2,500. Label the left column with the dates: March 20, June 20, September 22, and December 12. Label the middle column "Length of daylight." Label the right column "Angle of the Sun in the sky."

Be sure you have materials ready to add the following words to the Word Wall: *solar, daily, yearly (or annually), orbit*. Do **not** post these on the Wall until after your class has developed a shared understanding of their meaning.

Test student-facing videos:

- Sun Measurement Orientation 8.4 Lesson 3 Sun Measurement Orientation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- January - March 8.4 Lesson 3 Measuring the Sun: January - March (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- April - June 8.4 Lesson 3 Measuring the Sun: April - June (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- July - September 8.4 Lesson 3 Measuring the Sun: July - September (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
- October - December 8.4 Lesson 3 Measuring the Sun: October - December (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Watch teacher video, Measuring the Sun with Stellarium (Teacher Introduction) 8.4 Lesson 3 Teacher Measuring the Sun (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Physically Modeling the Earth–Sun System

- **Group size:** approximately 3 students per group
- **Setup:**
  - The light bulb should be equivalent to 60W (if you are using a bulb that measures in lumens this is often 800 lumens).
- **Notes for during the lab:**

- Make sure to have each group save their physical models created in this lesson. They will be reused in Lesson 6 and 7.

- **Safety:**
  - Use safety glasses/goggles with side shields (or indirectly vented chemical splash goggles) during the setup, hands-on, and takedown segments of the activity.
  - Use only GFI-protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
  - Use caution when working with light bulbs because they can cause skin burns or electric shock.
  - Use caution when using sharp tools and materials (e.g., wires, pins, etc.) because they can cut or puncture skin.
  - Immediately pick up any items on the floor (e.g., extension cords, etc.) in the work zone so they do not become a slip/fall hazard.
  - Use caution when working with glassware (e.g. bulbs) which can shatter if dropped and cut skin.
  - Have students ask the teacher where to safely place equipment and materials upon completing the lab activity.
  - Wash your hands with soap and water immediately after completing this activity.

Lesson 3 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will use a video planetarium software to observe the motion of the Sun through the sky. This entry point into thinking about seasonal patterns builds on first grade standards about the number of hours of daylight at different times of the year (1-ESS1-2) and the fifth grade standards for explaining day and night using a model of the Sun and Earth and the rotation of Earth around it axis (5-ESS1-2). Students then record data using NOAA websites to establish the long-term cyclical pattern of changes in the amount of daylight and angle of elevation of the Sun in the sky. Students use these observations to evaluate the accuracy of their current models. Students adjust their models, which allows them to build an understanding of how Earth's tilt and orbit around the Sun affect the amount of daylight and angle of elevation of the Sun in the sky.

Where We Are NOT Going

We do not explicitly state the degree of the tilt of Earth's axis. Earth's orbit around the Sun is in a circular pattern in this lesson. It is not explicitly stated that the orbit is elliptical; students will build this understanding and model in high school. We also do not identify what controls the motion of objects in the sky or how they were formed. In the fourth lesson set of the unit, students explore gravity, its interactions with objects in the sky, and formation of the solar system.

LEARNING PLAN FOR LESSON 3

1. Navigation

3 MIN

Materials: None

Additional Guidance

Connections to Me and My Community: In Lesson 1, students considered how changes in the length of a day impact their experience. In this lesson, students get the opportunity to explain this phenomenon by connecting a model of objects in space to the seasonal patterns they have experienced their whole lives.

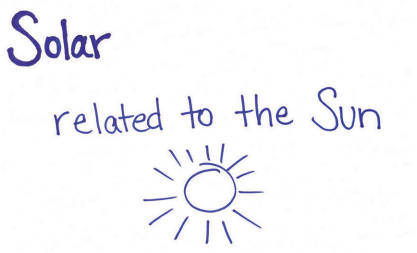
Review the front matter for this unit for an overview of how this unit is designed to help students see why the patterns in the sky are relevant to their lives, their communities, and life on Earth.

Brainstorm activities that occur during certain times of the year. Present **slide A**. Have students turn and talk with a partner to respond to the prompt, *"What are some changes in activities that occur during certain times of the year that are related to changes in the amount of sunlight?**

Solicit student ideas. Listen for students to mention activities such as the following:

- *Farm equipment on the road*
- *Farmer's markets or fruit stands popping up*
- *Hearing the ice cream truck*
- *Pools, golf courses, parks opening*
- *Ice cream stores/hacks opening*
- *Staying up or staying outside later*

As students share their brainstormed list of activities, record them on a piece of chart paper titled "Changes in activities that occur related to changes in the amount of sunlight over the year."



Transition to using a video of planetarium software to observe the Sun. Say, *We are together for less than a year for the entire time we are together for this class. Therefore, the patterns of the Sun that occur over a year or longer would be too long a period for us to directly observe. I have a video made with planetarium software that we can use to make observations of the Sun in a much shorter amount of time. Things that are related to the Sun are called "solar."* Let's look for solar patterns.*

*** Attending to Equity**
Supporting emergent multilingual students: It is important to organize activities in ways that create opportunities for students to engage in meaningful, accountable talk by emphasizing socially safe activity structures (e.g., small-group or partner work before a whole-class discussion). This is especially beneficial to multilingual students. For this reason, partner talk or small-group talk should precede whole-group discussion whenever possible to give students an opportunity to share their ideas with one or two peers before going public with the whole class.

*** Attending to Equity**
Supporting emergent multilingual students: If you teach in a linguistically diverse classroom, this is an opportunity to build on the language expertise of your students by soliciting student ideas about cognates. Cognates are words that are similar in both spelling and meaning. The word *solar* comes from the Latin word for the Sun: Sol. Sol has cognates across many languages, including Spanish and Portuguese (Sun = sol), French (Sun = soleil), Icelandic (Sun = sól), Italian (Sun = sole), and

Russian (Sun = солнце, read as solntse). Using cognates, teachers can support emerging multilingual students in making connections between new science vocabulary and their native language(s). This can reduce the vocabulary overload that they may experience in science. If you use a Word Wall or personal glossary to support your students' vocabulary learning, place cognates alongside the new vocabulary terms or include cognates in text using parentheses.

2. Make predictions about the sun.

5 MIN

Materials: None

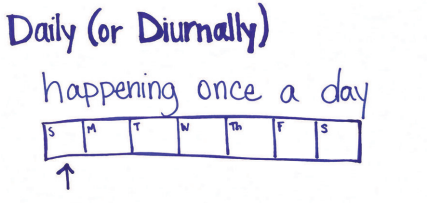
Make predictions about the Sun. Present **slide B**. Say, *What patterns do we think we are going to see related to the Sun over one day when we speed up time in the software?*

Suggested prompts	Sample student responses	Follow-up questions
What patterns will we notice in the sky when the Sun is up vs. when it's down?	*It will be dark when the Sun is down and light when the Sun is up.*	*What will happen to the stars in the sky when the Sun is up?*
What patterns will we see in the motion of the Sun?	*The Sun will rise in the east and set in the west.*	*(If students do not give cardinal directions such as north, south, east, west, you can push them for more details, but avoid playing "guess what's in my head." In other words, if students only identify the sunrise and sunset or that the Sun is in different places at the beginning and end of the day, this is sufficient.)*

Say, *Since day and night and sunrise and sunset occur every day, let's refer to them as daily patterns.**

Record these predictions at the front of the room:

- Daily (every day):
  - The sky will get light when the Sun is up, and we will not see the stars.



*** Attending to Equity**

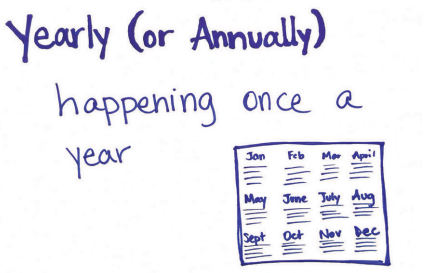
Supporting emergent multilingual students: If you have a linguistically diverse classroom and/or a large population of emergent multilingual students, this is another opportunity to build on students' language experiences, this time to make sense of the words *daily* and *yearly*. We chose **not** to use the words *diurnal* and *annual* in this unit to better align with students' everyday talk without losing scientific accuracy. But in some classrooms, *diurnal* and *annual* might be more familiar words because they are cognates to the Spanish words *día* and *año*. Consider what vocabulary your students will be the most comfortable with, and if you choose to use synonyms interchangeably during instruction, make it explicit by putting these

- The Sun will rise (in the east) and set (in the west).

Present **slide C**. Ask, *What about if we speed it up even more and watch the Sun over a year? What patterns will we see?* Because this is a more sophisticated set of patterns, ask students to turn and talk about this question for a minute before eliciting their ideas. Accept all predictions.

Look for students to suggest changes in where the Sun rises and sets or when the Sun rises and sets or how high it goes in the sky. Record at least one prediction at the front of the room underneath the daily prediction. Here are a few prediction examples:

- Yearly (every year):
  - The Sun will set later and earlier.
  - The Sun will get higher in the sky.
  - The Sun will rise and set in different places.



synonyms next to each other on a Word Wall. Regardless of what vocabulary you choose to use in your classroom, consider pausing for a moment to have students explain what *daily* and *yearly* (or *diurnal* and *annual*) mean in their own words, either in their notebooks or with a partner. When you use these words over the next couple of days, scaffold their use by adding a parenthetical explanation, for example: *What patterns did you see yearly (happening every year)?*

3. Observe the Sun with planetarium software.

20 MIN

Materials: *Observations of the Sun: Location* _____, computer, 8.4 Lesson 3 Measuring the Sun: January - March (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: April - June (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: July - September (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Measuring the Sun: October - December (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 3 Sun Measurement Orientation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), "Changes in sunlight and angle of the Sun in the sky over one year" poster

Make observations using sky video. Present **slide D** and group students into two large teams: one team that will measure changes in the amounts of daylight, and one team that will measure changes in the angle of the Sun in the sky. Consider student interest when splitting the class into two teams. Some students may be more interested in measuring changes of daylight or changes in the angle of the Sun in the sky.

Show the Sun Measurement Orientation video first to orient students to the videos they will use to make observations of the Sun in the sky. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Once students are in the two large teams, further split them into four groups that will measure data over certain months so students can take a more participatory role in the data collection. Handout *Observations of the Sun: Location* _____ and have the students decide on which groups will record, analyze and interpret data for which months.

*** Attending to Equity**
Universal Design for Learning: Encouraging students to reenact the patterns with physical actions helps students *express* the path of the Sun using a different modality. This helps students visualize the path of the Sun in the sky.

Additional Guidance

Each group will use a video to measure days during a grouping of months. Two groups should record information from January through March. Two groups should record information from April through June. Two groups should record information from July through September. Two groups should record information from October through December.

Alternate Activity

Instead of showing the video created with Stellarium software, you can demonstrate it using your desktop or have students download the software onto their devices to run the simulation instead. For more information on general use of Stellarium software see, *Stellarium Introduction Teacher Reference*. For guided information on how to show students changes in the Sun during a year see, *Observing the Sun with Stellarium*.

As groups collect and interpret data, rotate around the room and assist as needed. Once each of the team's smaller groups have recorded their data, have the whole team get together to complete their team's column on *Observations of the Sun: Location* _____.



Assessment Opportunity

Building towards: 3.A Use a graphical display (simulated motion from a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in solar elevation and length of day) in a large data set (across 6 months from a specific location on earth's surface).

What to look/listen for: Students collect data, using the videos, about the angle of the Sun in the sky or hours of daylight during the course of a year. Look for the following:

- The angle of the Sun in the sky increases from January to its greatest angle in June then decreases through December.
- The hours of daylight increases from January to its greatest amount in June and then decreased through December.

What to do: If students struggle with measuring the angle of the Sun in the sky, prompt them to examine the video and use a piece of paper to help make their measurements.

Share data in a Scientists Circle. Present **slide E** and have students move into a Scientists Circle. As the two teams share their data, record it on a piece of chart paper titled, "Changes in amount of sunlight and angle of the Sun at midday over one year." Instruct students to record the other team's data into *Observations of the Sun: Location* _____.

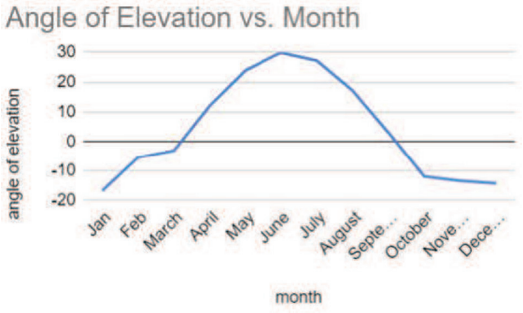
Additional Guidance

Students should know or have identified in earlier grade bands that it takes the Earth one year to make a complete trip around the Sun. This lesson builds upon that knowledge to develop the idea that there are repeated, cyclical patterns of hours of daylight and the angle of the Sun at midday as the Earth orbits the Sun.

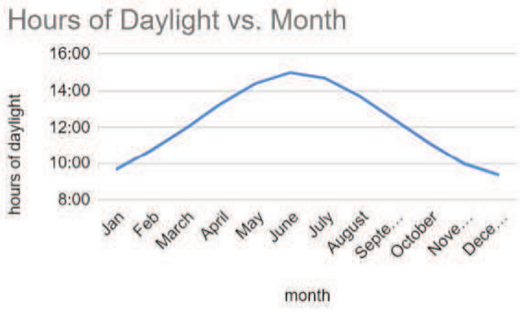
Point to the corresponding papers posted on the wall labeled with E, W, N, and S from Lesson 2.

Alternate Activity

Project a spreadsheet to record student data. You can then create a graph of the data, which would allow students to visualize the patterns easier for the next part of this activity. Graphs created should look similar to the images below.



Data Source: NOAA



Data Source: NOAA

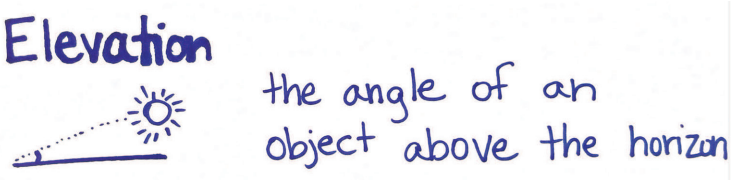
Identify patterns in the data. Present **slide F**. As students describe the pattern related to the angle of the Sun in the sky increasing or decreasing, have all students in the class reenact this pattern by pointing with their arms to the apparent path of motion the Sun takes across the sky when it is higher in the sky in the middle of the day versus when it is lower in the sky in the middle of the day.*

Suggested prompts	Sample student responses
What yearly patterns do you observe in the amount of sunlight?	*The amount of sunlight changes during the year.* *In January there were about 9 hours of daylight, but in June there were 15.*
What yearly patterns do you observe in the amount of sunlight?	*The angle of the Sun in the sky at midday changes during the year.* *The angle of the Sun in the sky in the middle of the day increases starting in January and then decreases starting in June.*

Suggested prompts	Sample student responses
You have described two different patterns. Let's think about how they might be connected to one another. When the amount of sunlight is increasing from one day to the next, what is also happening to the midday angle of the Sun in the sky?	*When the amount of sunlight increases, the angle of the Sun in the sky also increases.*
And when the amount of sunlight is decreasing from one day to the next, what is happening to the midday angle of the Sun in the sky?	*It is decreasing.*
So then what would you say/predict is happening to the amount of sunlight during the time of year when the midday angle of the Sun in the sky is decreasing?	*It would be decreasing too.*

Introduce elevation as a way to refer to the angle of the Sun. Once this description and physical reenactment of these changing angle patterns is shared, introduce the word *elevation* as a way that astronomers refer to the angle of an object above the horizon. Emphasize that this is different from the way we typically use elevation to refer to distance measurement upward, since it refers to an angle measurement instead, but is similar in that it is a measurement that refers to how far upward something is from another surface, which in this case is the Earth's surface at the horizon. Have students point their arms straight to the horizon and say this is considered an elevation of 0 degrees. Have students repeat this for an elevation of 90 degrees (straight overhead) and an elevation of 45 degrees.

Add this diagram to the Word Wall to represent an example of the Sun at an elevation of 30 degrees.



4. Initial Ideas and Navigation

17 MIN

Materials: *Sun Patterns Over Many Hundreds of Years*, computer (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Think back to previous lessons. Remind students of the Sun stories we heard in the previous lessons. Present **slide G**. Say, *Think back to the stories we have heard in the previous lessons. What connections can you make between those stories and changes in the Sun during the year?* Look for student responses like the following:

- Henges were used to mark some of the changes we recorded, like the longest day or the shortest day.
- They would mark the different times of the year, like changes in the seasons that went with changes in the Sun.

*** Attending to Equity**
Supporting emergent multilingual students: Depending on the goals of a lesson or the goals for a particular aspect of a lesson, it is helpful to intentionally group emerging multilingual students with certain

Share initial ideas about the scale of patterns. Present **slide H** and say, *Do you think these year-long patterns have happened over hundreds or thousands of years? Why or why not? Turn and talk with a partner.* Give partners a few minutes to talk before asking students to share their ideas. Accept all student ideas.

Examine changes in the Sun over thousands of years. Say, *I found a couple of websites that will let us record measurements from the National Oceanic and Atmospheric Administration, or NOAA*. Hand out *Sun Patterns Over Many Hundreds of Years* and present **slide I**. Explain to students that each group will be assigned a different year to record data on four different dates.

Assign each group to a different time span: 1,000 years, 1,500 years, 2,000 years, and 2,500 years. If you have more than four groups, add additional years in 500-year increments and add extra tables to *Sun Patterns Over Many Hundreds of Years* for students to record the additional groups' data in a later step.

Display the NOAA website with a computer to the class and make note of the location, latitude, and longitude. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) If your class decides to use your school's location, change the latitude and longitude accordingly. Say, *We will use this site to record sunrise, sunset, and determine the length of daylight.*

Display the website and show students how to change the latitude, longitude, and timezone to match that used with the first website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Say, *We will use this site to record solar elevation*. Remind students that we defined the word solar to describe the Sun. Say, *Remember, "solar" means related to the Sun*. Point out on the website where solar elevation is recorded.

Additional Guidance

Make sure that when using the two websites, the same location is used for both. The default for for the website is the geographic center of the contiguous United States. If you want to use your school's location, the data will be slightly different than that of the data in the sky videos, as the geographic center of the contiguous United States was used to generate the videos.

Have students get into groups to record the data.* As groups record data, rotate around the room and assist as needed.

Alternate Activity

If students are overwhelmed by the amount of data presented, consider providing them a data set using *Data from NOAA websites*. The location for these data will be the geographic center of the contiguous United States.

Tell students that they will share their data with the rest of the class tomorrow. Say, *Tomorrow, we will share our data with the other groups*.

End of day 1

peers. Sometimes this could be peers who know the same languages as them, while other times it could be peers whose English language development is slightly more advanced. It is important that this grouping be thoughtful and that it varies throughout the course of a unit so that students benefit from working with different peers.

5. Navigation

2 MIN

Materials: *Sun Patterns Over Many Hundreds of Years*

Remind students of where we left off last time. Say, *Last class we worked in groups to record data about changes in the Sun over a thousand years on Sun Patterns Over Many Hundreds of Years. Meet with your group to make sure you are ready to share your data with the class*. Have students get back into their groups and briefly prepare to share their data.

6. Building Understandings Discussion

15 MIN

Materials: *Sun Patterns Over Many Hundreds of Years*, "Changes in sunlight and angle of the Sun in the sky over hundreds of years" poster

Share group data with the class. Present **slide J**. Have groups share their data and record it on a piece of chart paper titled "Changes in sunlight and angle of the Sun in the sky over hundreds of years." Tell students to record the other group's data into *Sun Patterns Over Many Hundreds of Years*.

Analyze data with a partner. After the groups have shared their data, tell students to work with a partner to answer the data analysis questions on *Sun Patterns Over Many Hundreds of Years*. Allow partners about 7 minutes to complete the questions.



Assessment Opportunity

Building towards: 3.B Collect and produce data showing patterns of changes in daylight and the angle of elevation of the Sun in the sky to serve as evidence to evaluate the accuracy of an initial physical Earth–Sun System model.

What to look/listen for: Students collect data using NOAA websites to identify patterns of changes in daylight and the angle of elevation of the Sun in the sky over hundreds of years. Look for the following:

- Changes in the amount of daylight and angle of elevation of the Sun in the sky occur in a cyclical pattern, repeating over hundreds of years.

What to do: The concept that this is a repeated, cyclical pattern is important to establish so that students can use this data as evidence to examine the accuracy of the physical models created later in the lesson. If students are struggling to identify the patterns in the data because of how the data is structured by years, encourage them to re-write the data by months to make the yearly patterns more visible.

Lead a building understandings discussion. Present **slide K**.

Suggested prompts	Sample student responses
How has the amount of daylight changed over 500 years?	*It stayed the same or only changed by a couple of minutes.*
Over 1,000 years?	*It stayed the same or only changed by a couple of minutes.*
Over 1,500 years?	*It stayed the same or only changed by a couple of minutes.*

Suggested prompts	Sample student responses
How has the solar elevation changed over 500 years?	*They were pretty close.* *They changed by hundredths of degrees.*
Over 1,000 years?	*Some stayed the same, but others changed.* *Some changed by hundredths of degrees, and others changed by tenths of degrees.*
Over 1,500 years?	*They changed by tenths of degrees.*
What's the relationship between the solar elevation and amount of daylight over the hundreds of years?	*The higher the Sun is in the sky, the more daylight we have, so the Sun is taking a longer time to pass across the sky as it's going higher.*
How does this compare to the data you recorded using the videos of the simulation?	*The data from the websites matches the data we recorded when we measured solar elevation and length of daylight from the simulation.* *The data is not exactly the same, but the patterns are the same.*
How does this data help explain why or how different communities created rituals to help mark and predict changes in the patterns of daylight during a year?	*The changes in the Sun are stable and predictable.* *These changes follow a stable pattern over hundreds of years. So people could count on the same things happening with the Sun at the same time each year.*

7. Process patterns of the Sun in the sky.

10 MIN

Materials: science notebook, *A Model to Explain the Movements of Objects in the Sky*, "Patterns from the Sky" poster from Lesson 1

Connect patterns in the Sun to previous lessons. Have the "Patterns from the Sky" poster from Lesson 1 displayed. Present **slide L**.

*** Attending to Equity**
If your students suggest a different name with cultural significance, use that term instead. Several examples can be found online. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Suggested prompts	Sample student responses
What connections can we make between the patterns in the collected data in this lesson to the patterns identified by other civilizations we studied in earlier lessons?	*There are changes in the amount of daylight during the year.* *The longest days of the year occur during the summer solstice, which lines up with some of the henges.*
Look back at the model of the Earth–Sun–Moon system you made in Lesson 2, what sort of things would we need to make a physical model of that system in our own class?	*We would need a sphere to represent the Earth.* *We would need something to represent a person standing on the Earth's surface.* *We would need a light source for the Sun.* *We would need something to represent the North Star.*
What changes could we make to the parts of the physical model to see if the data we've collected can be explained by it?	*We could spin the Earth around its axis, once for every day.* *We would keep the axis pointed at one point, the North Star.* *We would spin it so that, for a person on Earth, it would look like the Sun is rising in the east and setting in the west.* *We could orbit the Earth around the Sun, once per year.*

Brainstorm materials to represent the Earth–Sun system. Say, *At the end of the last lesson, we considered some possible advantages and challenges with trying to represent our Earth in space system physically using manipulatives. Let's get ready to try a physical model approach for this system.*

Present **slide M**. Ask students to discuss the related questions in their groups. Then, after about 5 minutes, discuss them as a class.

Suggested prompts	Sample student responses
What parts of the system do we need to include in our physical model in order to explain the patterns of the Sun from one year to the next, and how could we represent them?	*We would need a sphere to represent the Earth.* *We would need something to represent a person standing on the Earth's surface.* *We would need a light source for the Sun.* *We would need something to represent the North Star.*
What changes could we make to the parts of the physical model to see if the data we've collected can be explained by it?	*We could spin the Earth around its axis, once for every day.* *We would keep the axis pointed at one point, the North Star.* *We would spin it so that, for a person on Earth, it would look like the Sun is rising in the east and setting in the west.* *We could orbit the Earth around the Sun, once per year.*

Introduce the term *Polaris*. Say, *We identified that Earth's axis points at the North Star. Scientists call the North Star, Polaris.* Take a moment to add the word *Polaris* to the class Word Wall.



Additional Guidance

In order to develop the understanding that Earth's axis is tilted, the physical models must include Earth's axis and Polaris. If students do not suggest we include Earth's axis or Polaris, ask, *What other parts are important to include that will help us determine Earth's orientation in space?*

Say, *I'll see if I can have some of those materials available so we can put these models together.*

8. Initial Class Physical Model of Earth-Sun System

15 MIN

Materials: Earth–Sun Modeling Demonstration, science notebook

Create a model map as a class. Present **slide N**. Tell students that we will make a model map in their notebooks for their physical Sun–Earth representations. You can use *Mapping the Model to the Earth–Sun System* to support students if they are not familiar with making a model map.

Additional Guidance

Model maps are useful when students are trying to make sense of a concept that is difficult to understand. The purpose is to map the elements of the physical (or conceptual) model to the real-world system we are trying to understand. A model map allows students to break the model into smaller pieces of information and then analyze what each part means. The first few times your students use a model map, you should go through a row with students to make sure they understand how to complete it. In addition, consider giving them some already completed sections. As students become more adept at mapping their models, you might fill in a few of the sections in the different columns and allow students to complete the map. Always leave at least one or two empty rows for them to add any additional parts to their maps.

Model the system at the front of the room. Ask students to get up and gather around a table at the front of the room. Follow the instruction steps below for a teacher demonstration. As you demonstrate each item, ask students to record it in the "Feature of the representation" column of their model maps along with, in the second column, the real-world feature it represents.

*** Attending to Equity**

Supporting Emergent Multilingual Students: When developing new vocabulary, strategies that may benefit emergent multilingual learners are to use student-friendly definitions, make connections to cognate words when possible, and include a visual representation of the word. It can be helpful to use gestures in addition to talking. For example, as you describe orbit you can make your hands it to fists and circle them around each other. Use these strategies throughout the unit for both "words we earn" and "words we encounter."

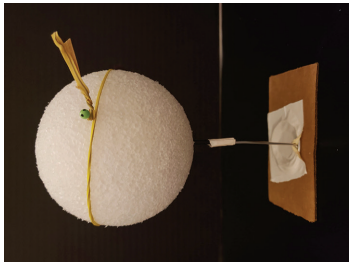
1. Turn off any classroom lights. Hold up a lamp and point out the safety concerns of using electrical devices. Remind students not to touch a hot lightbulb, to keep liquids away from electrical cords, and to be very careful whenever plugging in or unplugging an electrical device. Then show students how to turn on and off the lamp. Say, *This can be our Sun*. Give students a moment to record "Sun" in their model map in the second column as they record "Lamp" in the first column.



2. Hold up a foam sphere with a plastic coffee stirrer through the center and wire base sticking out through the middle. Say, *This can be our Earth, and the wire is the axis*. Then hold up the round push pin and tell students that this can represent us in the model. Say, *We need something to represent our perspective on Earth so that we can imagine what we see from our position. I'm going to stick this round push pin where we are*. If there is a globe in the classroom, point to our location on the globe and ask students to approximate where that location would be on the sphere before placing the push pin there. Draw little eyeballs on the push pin with a Sharpie marker to indicate perspective. Then put a rubber band around the globe at the same latitude as the round push pin. Tell the class, *This band represents the path that the observer will take around the globe as Earth spins. Another way to think about it is as a line of latitude.* Spin the globe so that students see that path. Give students a moment to record the sphere, the push pin, and the rubber band in their model maps along with the real-world feature that each represents.



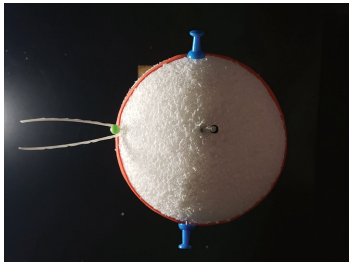
3. Tell students, *It's hard to tell where this person is looking so we can see what the angle of the Sun would be for them. I was thinking we could give this little person an arm so that they can point at the Sun for us*. Produce a twist-tie. and tell students you want to use this to represent the arm of the observer. Twist it around the push pin and use it to point at the lamp.



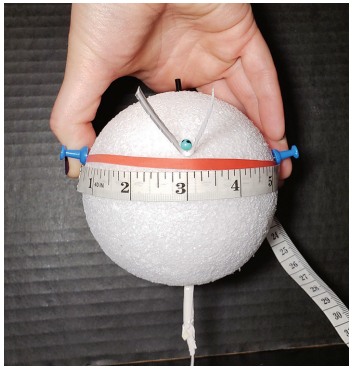
4. Hold the sphere next to the lamp, using a ruler to measure a foot away. Ask, *Which direction in the room do you think is Polaris?* Students should suggest that Polaris is above our heads making it so the axis points straight up and down. Then slowly spin the sphere counterclockwise so that students can see the push pin move from one side of the illuminated area to the other side. Ask, *When is it sunrise for us, and when is it sunset?* Have students turn and talk with a partner and then elicit ideas. Look for students to point to the moment that the round push pin moves into the light as sunrise and the moment that it moves back out of the light as sunset. Say, *Remember that the rubber band is the path of the observer through the light. So, this point here, where the observer push pin passes into the light, is sunrise, and this point here, where the observer push pin passes into the shadow, is sunset.* Give students a moment to record both of these in their model maps.



5. Show students the push pins and explain that we can use these to measure the distance between sunrise and sunset. Use **slide O** to illustrate this. Then have a student come up and place round push pins at sunrise and sunset, where the path of the observer (the rubber band) intersects with the line (indicated with the dashed line in the slide photo) between light and shadow at two places.



6. Display **slide P**. Have another student use the fabric tape to measure the path between the round round push pins. Round to the nearest half inch. Record this measurement on a piece of chart paper as position 1 or March 20. Have students also record this data in their notebooks. Then say, *OK, if this is now, where should I hold the sphere to model what the system will be like in three months, or May 20?* Look for students to suggest moving the sphere to the other side of the lamp.





7. Present **slide Q**. Repeat this process (steps 5 and 6) one quarter of the way around the circular path of the lightbulb, moving the sphere counterclockwise around the lamp if possible.

Round the measurement to the nearest half inch. Record this measurement on the chart paper as position 2 or May 20. Have students record this measurement and the following measurements in their science notebook. Repeat this process (steps 5 and 6) to measure halfway around the circular path of the lightbulb, and record the measurement on the chart paper as position 3 or September 22. Repeat this process (steps 5 and 6) one final time three quarters around the circular path of the lightbulb, and record the measurement on the piece of chart paper as position 4 or December 21.

Assessment Opportunity

Building towards: 3.B Collect and produce data showing patterns of changes in daylight and the angle of elevation of the Sun in the sky to serve as evidence to evaluate the accuracy of an initial physical Earth–Sun System model.

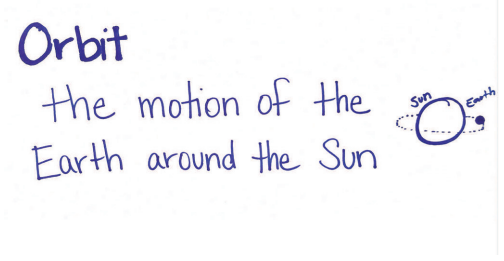
What to look/listen for: Students collect data showing the patterns of changes in daylight using a physical model. Look for students to relate the measurements made using the fabric tape measure to relative hours of daylight using comparison terminology like shorter, longer, or equal.

What to do: If students do not connect the length of daylight using the fabric tape measure to hours in the day, ask, *What relationship does the measurement we recorded in inches have to do with the hours of daylight?* Work with the class to agree that a certain measurement in inches would correspond to one hour of daylight.

Additional Guidance

Some students might suggest changing the distance from the lamp to the sphere at different places in the orbit. Ask those students why they think we should change the distance. Listen to their responses. The common student idea is that the Sun is closer to Earth in summer. If this comes up, do not downplay it. Instead, highlight the idea for the class and record this prediction at the front of the room. Tell students that you find it very interesting but that you are not convinced and that we will investigate the idea in the next lesson.

Introduce the word *orbit*. If students are using a variety of words to describe the motion of the Earth around the Sun, take a moment to explain that scientists describe this particular motion as an orbit, add the word orbit to the class Word Wall. Even though many students will built out the ideas of orbit in earlier grades, it is important to take this moment to check in prior knowledge and make sure students are using it in the same way.*



9. Navigation

3 MIN

Materials: science notebook, *Sun Patterns Over Many Hundreds of Years*, *Mapping the Model to the Earth–Sun System* (optional)



Problematize differences in data. Present **slide R** and have students check to make sure they have filled out *Mapping the Model to the Earth–Sun System*. Have students stop and jot to respond to the prompts on the slide before asking for student responses. Ask, *Based on the measurements you have made, are our models accurate? How well does what you measured with our physical model match the data we recorded from the NOAA websites?* Look for student responses like the following:

- Our models can't be accurate because the data doesn't match.
- The data we measured with our physical model doesn't match the data we recorded from the NOAA websites.

Assessment Opportunity

Building towards: 3.B Collect and produce data showing patterns of changes in daylight and the angle of elevation of the Sun in the sky to serve as evidence to evaluate the accuracy of the Earth–Sun system model.

What to look/listen for: Students should identify that their models do not reflect the data they have collected. Look for the following:

- Changes in the amount of daylight and angle of elevation of the Sun in the sky occur in a regular, repetitive, and cyclical pattern.

What to do: If students do not call out that the data they collected from the video and NOAA websites does not match the data they collected from measuring the physical models, have students refer back to *Observations of the Sun: Location _____*, *Sun Patterns Over Many Hundreds of Years*, and their science notebook. Point out that the changes in daylight and the angle of elevation of the Sun in the sky are not reflected in the measurements we recorded using the physical models.

Say, *It sounds like we have some results that suggest our models might need to be revised in order to account for the patterns we think we should see year after year. Let's plan to work on revising our models to better explain the patterns from our NOAA data tomorrow.*

End of day 2

10. Navigation

5 MIN

Materials: None

Remind students of where we left off last class. Say, *Think back to what we did last class. Did the data we measured with our physical model match the data we recorded from the NOAA websites?* Students will say it did not. Present **slide S** and say, *Let's adjust our model to measure a 15-hour day and a 9-hour night. Look at our modeling assumptions:*

- *Earth spins on its axis.*
- *Earth's axis points toward Polaris.*

- *Polaris is directly above us.*
- *The hours of daylight and nighttime flip during the year.*

Which of the modeling assumptions would you change that would let us reach 15 hours of daylight? Go back to your group and think about which assumption we could change. After a few minutes, ask a few groups to share their ideas. Look for groups to say that the only assumption we can change is that the star's location isn't directly above us. Say, *Great! Go back to your stations and figure out where Polaris might be in the sky.*

Additional Guidance

Students should focus on changes that don't require a change in the distance from the Earth to the Sun but should focus on changing the angle of the sunlight on the Earth.

11. (Physically) Revise the model of the Earth-Sun system. 10 MIN

Materials: Physically Modeling the Earth–Sun System, science notebook, *Sun Patterns Over Many Hundreds of Years*, *Modeling the Earth–Sun System*, *Mapping the Model to the Earth–Sun System* (optional), chart paper, markers

Model the Earth–Sun system using *Modeling the Earth–Sun System*. Present **slide T**. Ask students to collect the materials for their group. Each group will need a 4-inch sphere, 2 push pins, 1 round push pin, 1 60W light bulb, 1 bulb socket, 1 extension cord with power strip, 1 plastic clamp for keeping the power strip upright, 12 inches of wire, a fabric tape measure, a Sharpie marker, and a ruler.

Using *Modeling the Earth–Sun System* to record the data, students will measure the length of a day with push pins and the fabric tape measure. They will do this at each of four positions around the lamp (12 o'clock, 3 o'clock, 6 o'clock, and 9 o'clock). For each position on the 2D model shown on *Modeling the Earth–Sun System*, students will need to record in inches the length of the Sun's path for the observer and predict the shape of the Sun's apparent path for the observer on a screen shot of the Stellarium skyline in the table. Walk around the classroom and make sure that students are trying to change the orientation of Earth in space by pointing the wire at a different part of the room other than straight above to better match the data we recorded from the NOAA websites.

Alternate Activity

An alternative handout of this lab is available at *Example Modeling the Earth-Sun System Data* which includes images students can use to collect data, in case your student(s) are not able to complete this lab in the classroom.

When students are done taking data, they should finish filling in the model map, either in their notebooks or using *Mapping the Model to the Earth–Sun System*.

12. Building Understandings Discussion

13 MIN

Materials: science notebook, *Sun Patterns Over Many Hundreds of Years*, *Modeling the Earth–Sun System*

Reflect on changes to the model. Have groups work together to reflect on the changes they made to their physical models on *Modeling the Earth–Sun System*. As the groups work, rotate around the room and assist as needed.

Lead a Building Understandings Discussion to reflect on physical model adjustments. Present **slide U.**

Suggested prompt	Sample student responses
What adjustment did you make to your model that was the best fit for the data we recorded?	*We had to aim the axis at a different star in the room.* *We changed the Earth from being straight up and down to being tilted in space.*

Present **slide V** and discuss the questions on the slide.

Suggested prompts	Sample student responses
How did adjusting the orientation (tilt) of the Earth affect the amount of sunlight on the surface?	*We were able to see that it changed during the year. Some parts of the year, the amount of daylight was shorter and other parts it was longer.*
How did adjusting the orientation (tilt) of the Earth affect the path of the Sun in the sky and the angle of the elevation of the Sun in the sky?	*The path of the Sun changed so that it would take a longer path across the sky during days with more daylight and a shorter path across the sky during the days with less daylight.* *When the path is longer, the Sun's elevation is higher in the sky. When the path is shorter, the Sun's elevation is lower in the sky.*
How does this change where we need to position Polaris in our model?	*It means that in our models, we need to move the location of Polaris so that north isn't straight above us, but off to the side a bit.*

13. Update Progress Trackers.

10 MIN

Materials: science notebook

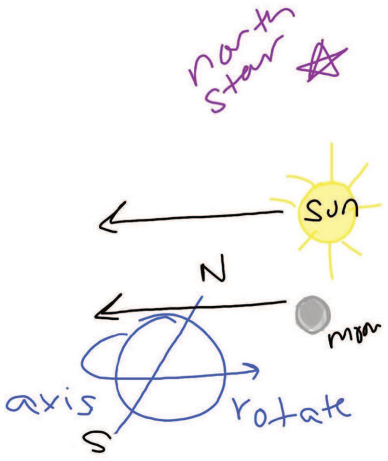
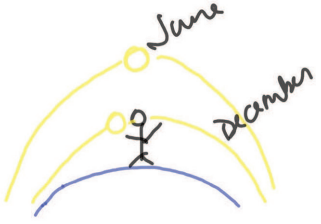
Update Progress Trackers to reflect new understandings. Present **slide W** and ask, *What new interactions / relationships should we include in our models?* Look for student responses like:

- The Earth is tilted toward Polaris.
- Polaris isn't directly above Earth, but off to the side.
- We should show changes in the amount of daylight and the path of the Sun and its elevation in the sky during different parts of the year.

Additional Guidance

Students may struggle with how to represent the changes in the amount of daylight and angle of the Sun in the sky during different parts of the year. Refer them to how they represented the path of the Sun in *Modeling the Earth–Sun System*.

Have students update their models and add their new understandings to their Progress Trackers. Use student updates to their Progress Trackers as a formative assessment opportunity. A sample revised model is shown in the sample Progress Tracker entries below.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
How can we explain the Sun's path change over time?	Polaris (or other agreed-upon term) doesn't move in the sky because Earth's axis is pointed toward it.  The height and path of the Sun in the sky changes during the year. 	Answers will vary, but some sample ideas could include the following: • People can use this star to navigate and travel because it's in the same position. • I get to stay up later because there are more hours of daylight.

Assessment Opportunity

Building towards: 3.C Revise a model of the patterns of movement of the Earth around the Sun to explain changes in the amount of sunlight and angle of elevation of the Sun in the sky during the year due to Earth's axis being tilted toward Polaris.

What to look/listen for: Models should identify the patterns of movement of the Earth around the Sun during a year to explain why there are cyclical changes in the amount of daylight and angle of elevation of the Sun in the sky. Look for the following:

- Earth's axis is tilted at an angle toward Polaris.
- As the Earth orbits around the Sun, differences in the amount of daylight and angle of elevation of the Sun in the sky change during certain times of the year in a repeating pattern.

What to do: Use your review of student-revised models to make sure they understand that Earth's axis is tilted and points toward Polaris. This understanding is key for moving forward in the unit. If students are missing this understanding, ask them, *What would explain why the amount of daylight and angle of elevation of the Sun in the sky changes during the year?* Or *What impact does Earth's orientation in space have on the amount of sunlight or the angle of elevation of the Sun in the sky during the year?* Have students revisit the patterns they identified earlier in the lesson to provide evidence for their thinking.

14. Navigation

5 MIN

Materials: science notebook, "Activities that happen when the amount of sunlight changes" poster

Make connections about Earth's tilt to students' lives. Ask, *Why does Earth's tilt matter to you?* Have students stop-and-jot their responses in their science notebook. Ask a few students to share their responses. (*Accept all responses.*)

Brainstorm other phenomena associated with Earth's tilt. Present **slide X**. Have students turn and talk with a partner to brainstorm a list of other phenomena and identify which of the "Activities that happen when the amount of sunlight changes" poster from Day 1 could be explained by Earth's tilt. Look for student responses like:

- *seasons, and*
- *changes in temperature.*

ADDITIONAL LESSON 3 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

In middle school math, students are expected to draw comparative inferences about two populations. The following seventh grade standard is from the common core state standards initiative:

CCSS.MATH.CONTENT.7.SP.B.3 Informally assess the degree of visual overlap of two numerical data distributions with similar variabilities, measuring the difference between the centers by expressing it as a multiple of a measure of variability. For example, *the mean height of players on the basketball team is 10 cm greater than the mean height of players on the soccer team, about twice the variability (mean absolute deviation) on either team; on a dot plot, the separation between the two distributions of heights is noticeable*. In this lesson, students compare numerical measurements of hours of daylight to distance of daylight on a physical model to determine similarities in data as a way to evaluate the accuracy of their model.

LESSON 4

How do these changes in sunlight impact us here on Earth?

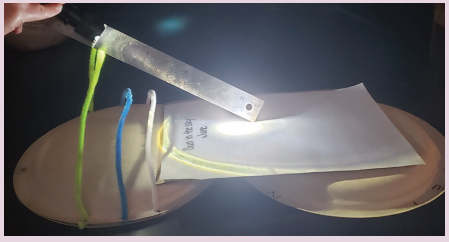
Previous Lesson

We watched a video of the simulated motion of the Sun through the sky over a day for different parts of the year. We noticed that in summer the apparent path of the Sun in the sky is higher and daytime is longer. We created physical models to see if our understanding about why this is happening is correct. We revised our model of the system in small groups to try to account for changes in the amount of daylight. We revised our drawn models to show the changed location of Polaris and Earth's tilted axis. We wondered what other phenomena can be explained by Earth's tilt and decided to study that next.

This Lesson

Investigation

2 DAYS



We analyze seasonal temperature data from two cities in the United States and argue that changes in Earth's distance from the Sun do not explain seasonal temperature differences. We develop a physical model and use it to collect data on changes of sunlight energy on Earth's surface as a result of changes in solar elevation. We wonder if this model also helps explain seasonal temperature differences in other parts of the world. We develop a Gotta-Have-It checklist and complete an assessment applying our models to seasonal temperature data from Australia.

Next Lesson

We will investigate patterns in Manhattanhenge. We will revise a model of the Manhattan phenomenon. We will revisit the Driving Question Board to connect what questions we have answered and what questions remain. We will decide to make observations of the Moon.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

4.A Develop, revise, and use models of the Earth-Sun system to create mathematical relationships of the seasonal patterns of the position of the Sun in the sky and of temperatures over the surface of Earth.

4.B Develop and use models of the Earth-Sun system to explain the cause-and-effect relationships between Earth's tilt, solar elevation, and sunlight energy on Earth's surface to explain seasonal temperature differences.

What Students Will Figure Out

- Solar elevation causes differences in the intensity of light reaching Earth's surface throughout the year.
- Higher solar elevation results in more direct sunlight and greater light energy reaching Earth's surface causing higher temperatures.
- Lower solar elevation results in sunlight being more spread out and less light energy reaching Earth's surface causing lower temperatures.

- When the sunlight is direct on the top half of Earth (the Northern Hemisphere), it is at an angle in the Southern Hemisphere, and vice versa. This is one reason (in addition to corresponding changes to the amount of daylight hours) why the seasonal patterns are the opposite in places like Australia and South Africa compared to our area.

Lesson 4 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION** Identify connections between amount of daylight and seasonal temperature changes.	A-C	
2	10 min	**EXAMINE SEASONAL TEMPERATURE DATA** Examine data to determine the relationship between Earth's distance from the Sun and monthly temperatures.	D-E	*Seasonal Temperature Data*
3	20 min	**MODEL AND EXPLAIN SEASONAL TEMPERATURE VARIATION** Develop a physical model to explain that seasonal temperature variation is caused by differences in the concentration of sunlight on Earth's surface.	F-G	chart paper, Modeling Sunlight Angles
4	7 min	**BUILD UNDERSTANDING ABOUT SEASONAL TEMPERATURE DIFFERENCES** Build understanding about the relationship between solar elevation and intensity of light on Earth's surface to explain seasonal temperature differences in the Northern Hemisphere.	H-I	*Defining Seasons* or the NOAA website (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), light energy per square of graph paper chart
				End of day 1
5	4 min	**NAVIGATION: UPDATE PROGRESS TRACKERS** Update Progress Trackers to reflect new understandings.	J	
6	4 min	**REVISIT THE LESSON 1 PODCASTS** Revisit the podcasts to see if our Earth-Sun system model can answer some of our questions about seasonal differences.	K	
7	12 min	**CREATE A GOTTA-HAVE-IT CHECKLIST TO EXPLAIN DIFFERENCES IN SEASONAL TEMPERATURE AND OPPOSING SEASONS IN DIFFERENT HEMISPHERES** Students work in pairs to review their artifacts from Lessons 1 to 4 and then as a class decide on what ideas should be included in our models and explanations.	L	*Lesson 4 Gotta-Have-It Checklist*, chart paper, markers

Part	Duration	Summary	Slide	Materials
8	20 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Students individually demonstrate understanding on an assessment about two phenomena from the podcasts.	M-N	*What causes the seasons in Australia and why are they opposite of our seasons?*, *The Equator, the Midnight Sun, and the Analemma* (optional), Patterns and Phenomena in the Sky poster (optional)
9	5 min	**NAVIGATION** Navigate to the next lesson.	O	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 4, students are ready to read Student Reader Collection 1 and then respond to the writing exercise.		Student Reader Collection 1: *Sky Watching Since Days of Old*

Lesson 4 • Materials List

	per student	per group	per class
Modeling Sunlight Angles materials	• *Modeling Sunlight Angles* • safety goggles	• 3 10-inch paper plates • 5 12-inch pipe cleaners (2 sets of 2 in 2 different colors and 1 additional in a third color) • 3 pieces of graph paper (1 cm squares) • a 7.5x11-inch piece of cardboard • a protractor • a ruler • a flashlight • a pencil • a marker • scissors • tape	

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • *Seasonal Temperature Data* • *Defining Seasons* or the NOAA website (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Lesson 4 Gotta-Have-It Checklist* • *What causes the seasons in Australia and why are they opposite of our seasons?* • *The Equator, the Midnight Sun, and the Analemma* (optional)		• chart paper • light energy per square of graph paper chart • markers • Patterns and Phenomena in the Sky poster (optional)

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Make sure students can publicly view and access the Phenomena and Patterns in the Sky poster.

Modeling Sunlight Angles Lab

- **Group size:** 3–4 students
- **Setup:**
  - Have the following materials ready, per group
    - 3 10-inch paper plates
    - 5 12-inch pipe cleaners in 3 colors (2 sets of 2 in 2 different colors and 1 in a third color)
    - 3 pieces of graph paper (1 cm squares)
    - 1 7.5x11-inch piece of cardboard
    - 1 flashlight (with batteries)
    - 1 ruler and 1 protractor
    - 1 pencil and 1 marker
    - scissors, tape
  - Trim the cardboard (either purchased or recycled from boxes) to make sure it measures 7.5x11-inches. These pieces can be reused by each class.

- **Safety:**
  - Use safety glasses/goggles with side shields (or indirectly vented chemical splash goggles) during the setup, hands-on, and takedown segments of the activity.
  - Use only GFI-protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
  - Use caution when working with light bulbs because they can cause skin burns or electric shock.
  - Use caution when using sharp tools and materials (e.g., wires, pins, etc.) because they can cut or puncture skin.
  - Immediately pick up any items on the floor (e.g., extension cords, etc.) in the work zone so they do not become a slip/fall hazard.
  - Use caution when working with glassware (e.g., bulbs) which can shatter if dropped and cut skin.
  - Have students ask the teacher where to safely place equipment and materials upon completing the lab activity.
  - Wash your hands with soap and water immediately after completing this activity.
- **Storage:** For long-term storage, remove batteries from flashlights to store in a cool, dry place.



Lesson 4 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will use seasonal temperature data and distance from the Earth to the Sun during its orbit to identify patterns. This entry point into thinking about seasonal temperature patterns builds on third grade standards about typical weather conditions at different times of year (3-ESS2-2) and fifth grade standards for explaining day and night using a model of the Sun and Earth and the rotation of Earth around it axis (5-ESS1-2). Students then build a physical model tracing the Sun's path at different times of the year and use a flashlight to record data to pattern of changes in the amount of energy on Earth's surface and angle of elevation of the Sun in the sky. Students use these observations to explain the relationships between Earth's tilt, solar elevation, and seasonal temperature differences during Earth's orbit.

Where We Are NOT Going

We do not explicitly state the degree of the tilt of Earth's axis. Students establish that Earth's orbit around the Sun is not a perfect circle in this lesson. It is not explicitly stated that the orbit is elliptical; students will build this understanding and model in high school. We also do not identify what controls the motion of objects in the sky or how they were formed. In the fourth lesson set of the unit, students explore gravity, its interactions with objects in the sky, and the formation of the solar system.

The energy from the flashlight is determined by reading the number of watts it is rated. Watts are a measure of rate of energy use (joules per second). No attempt is made to identify watts as a rate of energy use.

LEARNING PLAN FOR LESSON 4

1. Navigation

8 MIN

Materials: science notebook

Share other phenomena associated with Earth's tilt. Present **slide A**. Say, *after we updated our Earth-Sun model to include tilt, we started identifying phenomena on Earth or activities that happen when the amount of sunlight changes. Did we think we could explain with tilt? What were some of those phenomena or activities that we thought could be explained with tilt?*

- Seasons
- Changes in temperature

Connect hours of daylight with temperature. Present **slide B** and say, *Let's look at the four dates we used to measure daylength and solar elevation. How would you describe the temperatures around those four dates?* Look for students to identify that in March the weather is cold, gradually gets warmer toward June, starts to cool down in September, and is cold in December.

Additional Guidance

If your students struggle to identify trends in temperatures for the four dates or want more specific information, access your local area's temperature data from the NOAA website or a local meteorologist. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Say, *Think about the kinds of weather we have in March and September. Remember, when we recorded the amount of daylight and solar elevation during those dates, they were both about the same. Take a moment to stop and jot in your science notebooks about the prompt on the slide.* Give students a few minutes to stop and jot and respond to the prompt, *If the amount of daylight in March and September is about the same, why do you think there is such a difference in temperatures?* Then ask for a few students to share their answers. Accept all student responses.

Additional Guidance

Connections to Me and My Community: In Lesson 3, students considered how changes in the temperature impact their experience. In this lesson, students get an opportunity to connect their experiences to others in different locations on Earth. Review the front matter for this unit for an overview of how this unit is designed to help students see why the patterns in the sky are relevant to their lives, their communities, and life on Earth.

Identify initial ideas about seasonal temperature changes. Present **slide C**.

Suggested prompts	Sample student responses
How could we use what is in our Progress Trackers and models to explain seasons?	*Maybe when the Sun shines on us more, the temperature gets hotter in certain parts of the year.* *During different parts of the year, or the seasons, we get different amounts of sunlight because of the tilt.*
How does tilt help explain seasons?	*The tilt changes how much sunlight reaches us.* *The tilt changes how close or far away we are from the Sun.* *The tilt affects how long the Sun shines on the surface at any location and the angle of that light. These may affect how much energy that spot on Earth receives at different times of the year.*

2. Examine seasonal temperature data.

10 MIN

Materials: *Seasonal Temperature Data*

Examine differences in seasonal temperature and distance from the Sun. Present **slide D** and distribute *Seasonal Temperature Data*. Have students get into small groups to examine the seasonal temperature data using the prompts on *Seasonal Temperature Data*. As students work in groups to examine the data, rotate around the room and assist as needed.*

Lead a Building Understandings Discussion.* Present **slide E**.

Suggested prompts	Sample student responses
How did the average high temperature of both cities compare?	*They followed the same monthly pattern, both increase and decrease during the same months of the year.*
What pattern is there between temperature and the average distance of Earth from the Sun?	*The higher the temperature, the farther away we are from the Sun. The lower the temperature, the closer we are to the Sun.*
So if we are tilted toward the Sun in the summer but are farther away from the Sun, what point on Earth do you think they might use to measure distance from Earth to the Sun?	*It needs to be a place that doesn't tilt toward or away from the Sun much during the orbit. So maybe the middle of Earth, like the equator.*
The data shows us that during some parts of the year, Earth is closer to the Sun, and during other parts of the year, Earth is farther from the Sun. What could that mean for the shape of Earth's orbit?	*The orbit can't be a perfect circle because that would mean that the distance doesn't change during the year.*

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
Students should closely examine the average distance of Earth from the Sun in order to come to the conclusion that as temperatures of the cities increase, the distance between Earth and the Sun decreases. If students do not identify this pattern, call their attention to distance measurements. If students are using miles, point out that in the millions place the numbers during the winter are smaller than the numbers during the summer. If students are using kilometers, point out that in the tens of millions place the numbers during the winter are smaller than the numbers during the summer.

Suggested prompts	Sample student responses
What new questions does this data raise for you?	*If the distance from the Sun can't explain the temperature differences across a year (seasons), what can?* *What causes it to be warmer in the summer (in the Northern Hemisphere) and cooler in the winter then, if it's not because we are closer to the Sun?*
What else could help us explain this seasonal temperature pattern? What other data might help us account for this?	*Maybe how high the Sun is in the sky, the solar elevation?* *Maybe how many hours of sunlight we get?*

Additional Guidance

If students do not identify that solar elevation data may help us figure out the pattern, say, *Pretend you are outside during a sunny day. What part of the day would be the hottest part of the day? why?* Look for students to identify that the hottest part of the day would be around noon, a bit afternoon, or midday because that's when the Sun is the highest in the sky. Then ask, *What data have we recorded is similar to the reason for midday being the hottest part of the day?* Look for students to say solar elevation.

* Supporting Students in Three-Dimensional Learning

Lessons 1-7 primarily focused on portions of the following performance expectation: **MSESS1-1**: Develop and use a model of the Earth-Sun-Moon system to describe the cyclic patterns of lunar phases, eclipses of the Sun and Moon, and seasons. This building understanding discussion is an opportunity to generalize across the patterns of the Sun to help students see how the cyclic patterns of the Earth-Sun system can be explained using models. Emphasize how the components and patterns identified in the Earth-Sun system and those identified in the performance expectation work together, highlighting the role of orbit in the models using probing questions during discussion. When students describe the motions that explain the seasonal changes, push them to go further and explain the "why" of these changes: tilt and location of Earth in its orbit around the Sun. (Students are not expected to identify a specific shape associated with Earth's orbit around the Sun, only that it is not a perfect circle. In high school, students explore Kepler's Laws of Planetary Motion as a way to determine shapes of different orbits.) Make this explicit for students by summarizing, *Wow, we have identified a lot of patterns related to the Sun, and they all seemed very different at first! But by developing models of the Earth-*

Sun system in space, we were able to explain how tilt and orbit cause predictable changes in these systems and how those changes cause the seasons we experience and changes of the Sun we see in the sky.

3. Model and explain seasonal temperature variation.

20 MIN

Materials: *Modeling Sunlight Angles*, science notebook, chart paper

Develop a physical model to explain seasonal temperature variation. Say, *We already know that the amount of time the Sun is out increases as we move toward summer and decreases as we move toward winter. That seems like an important factor to consider when trying to explain seasonal temperature differences. But we also know that the Sun is higher up in the sky in the summer than in the winter. Let's collect some data on this other factor to see if the Sun being up in the sky higher in the summer could be contributing to why it is warmer, by modeling this relationship.* Present **slide F** and hand out *Modeling Sunlight Angles*.

Organize students into groups of 2–3. Each group of students will need 3 10-inch paper plates, 5 12-inch pipe cleaners (2 sets of 2 in 2 different colors and 1 additional in a third color), 3 pieces of graph paper (1 cm squares), a 7.5x11-inch piece of cardboard, a protractor, a ruler, a flashlight, a pencil, scissors, and tape. Students should follow the directions section on *Modeling Sunlight Angles* to count the number of squares of graph paper illuminated when the flashlight is held at each of the different solar elevations mapped out with the pipe cleaners.

Alternate Activity

In case students are not able to complete this lab in the classroom sample, a video of the investigation is available 8.4 Lesson 4 Modeling Sunlight Angles Investigation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) and investigation data are available in *Graph Paper Images: Modeling Sunlight Angles* to complete the making sense section on *Modeling Sunlight Angles*.

Present **slide G**. Once groups have gathered their data, have them use the making sense section on *Modeling Sunlight Angles* to calculate watts per square to establish how concentrated the light is for each flashlight position.

When students are finished, they should add the number of watts per square they determined to the three-column chart you have created at the front of the room for this purpose, labeled "Sun in the sky: December," "Sun in the sky: March & September," and "Sun in the sky: June." Example data (table):

Sun in the sky: June (watts per square)	Sun in the sky: March & September (watts per square)	Sun in the sky: December (watts per square)
0.169	0.110	0.099
0.167	0.116	0.096
0.178	0.098	0.102

Calculate an average to compare data. Quickly average the data on each column of the chart to allow students to compare conditions. Students should be comfortable calculating averages (this is a skill then developed in sixth grade mathematics). It is up to you if you want to use this as an opportunity for all of them to practice this quantitative skill or have just a few students calculate it for the class before recording the number on the poster.

Alternate Activity

To help students understand the idea of concentration, you might consider exploring the analogy of frosting on a cupcake. When you take one tub of frosting and spread the whole thing over a cupcake, the frosting (energy) will be very concentrated (more frosting in each bite). But when you spread that same tub of frosting on a fullsized cake, the frosting (energy) will be spread out, so you will get less frosting in each bite.

4. Build understanding about seasonal temperature differences.

7 MIN

Materials: *Defining Seasons* or the NOAA website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lead a Building Understandings Discussion to explain seasonal temperature differences. Present **slide H**.



Suggested prompts	Sample student responses
How do the angles of the pipe cleaners relate to the solar elevation measurements we made?	*They weren't exactly the same, but they showed a difference in the elevation of the Sun during different times of the year.*
What pattern do you see in the energy from light per square of paper data?	*The greater the angle of the pipe cleaners, the more energy from light per square of paper there is.* *The lower the angle of the pipe cleaners, the less energy from light per square of paper there is.*
What relationship was there between the angle of the Sun in the sky and the watts per square? why?	*As the angle, or solar elevation, increased so did the watts per square or the opposite because when the flashlight (Sun) was higher, the light (sunlight) was more concentrated, more direct, more dense, or there was more of it per square.*
How can we use this relationship to help us explain why it is warmer in the summer here and colder in the winter?	*When the Sun is higher in the sky, sunlight is more concentrated on Earth's surface. This heats the surface up more, which causes warmer temperatures.* *When the Sun is lower in the sky, sunlight is less concentrated on Earth's surface. This heats up the surface less, which causes colder temperatures.*

Suggested prompts	Sample student responses
And what else do we know about the amount of daylight changes over the year that could also be contributing to the seasonal temperature changes.	*The amount of daylight hours increases as we get closer to summer, and the amount of daylight hours decreases as we get closer to winter.*
As the Earth goes around the Sun, what is it about its orbit that causes both the amount of sunlight and how directly that sunlight falls on the surface to increase as we move from winter toward summer and decrease as we move from summer toward winter?	*The tilt of the Earth.* *Our hemisphere (the Northern Hemisphere) is tilted toward the Sun in the summer and tilted away from it in the winter.*

Assessment Opportunity

Building towards: 4.A Develop, revise, and use models of the Earth-Sun system to create mathematical relationships of the seasonal patterns of the position of the Sun in the sky and of temperatures over the surface of Earth.

What to look/listen for: See *Key for Modeling Sunlight Angles* for guidance. Students should make a connection between their model and solar elevation data to develop an explanation for the changes in intensity of sunlight on Earth's surface at different times of the year. Students may identify that more of the surface is receiving sunlight, which heats up the ground and contributes to an increase in temperatures. They should also connect the increase in the amount of daylight hours to this increase in temperature.

What to do: If students do not make the connection that sunlight heats up Earth's surface, prompt them to think about differences in how they feel standing in sunlight versus the shade to call back to their prior knowledge. If students do not connect light energy per square on graph paper's relationship to intensity of light, ask them to share their noticings about the apparent brightness of the light on the graph paper.

It is common for students to combine their ideas about proximity and warmth with the new ideas about the tilt of Earth to form a hybrid conceptual model for the system where proximity is still the primary cause of temperature patterns. If students were very convinced that distance from the Earth to the Sun was a factor in causing seasonal temperature change, take the time here to make a connection back to *Seasonal Temperature Data* to remind students that the data does not support that explanation, but the results from this investigation explain seasonal temperature change better. Have students take a moment to re-examine the distance data provided in the handout to understand that during the winter, the part of Earth where we live is closer to the Sun in its orbit.

If students are struggling with the connection between energy and temperature, remind them of what we figured out in *Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit)*: that more energy transferred to Earth's surface translates to more movement of the particles, which means higher temperatures.

Discuss initial ideas about how we explain seasons. Present **slide I** and tell students to turn and talk with a partner about the prompt on the slide: How do we know when one season ends and another begins?

Look for students to mention the calendar dates we've used in class, changes in weather, or changes in the amount of daylight. Handout *Defining Seasons* or provide students with the link to the NOAA website (See the **Online Resources Guide** for a link to

this item. **www.coreknowledge.org/cksci-online-resources**) and say, *I have a reading that might help us figure out how scientists determine when one season ends and another season begins. Read this tonight and come back next time ready to tell us what you think - which of these ways of marking seasons is most relevant to you? Why? It would be really great to talk with someone else about seasons, too - tell them what you've figured out in class and ask them what they think about the information you find in this article.*

Home Learning Opportunity



Note that the information in this article is supplemental and if students do not have a chance to read it, it will not hinder their understanding of the ideas in this unit. Home learning work should not be scored.

Encourage students to share this article with someone else - a friend, a trusted adult, or even a younger sibling. Ask students to read the article, possibly with that other person, and then talk about how they think about seasons and connections they might have with seasonal changes, equinoxes, and/or solstices.

If time allows, you might choose to have your students read this article with a partner during class instead of taking it home.

End of day 1

5. Navigation: Update Progress Tracker

4 MIN

Materials: science notebook

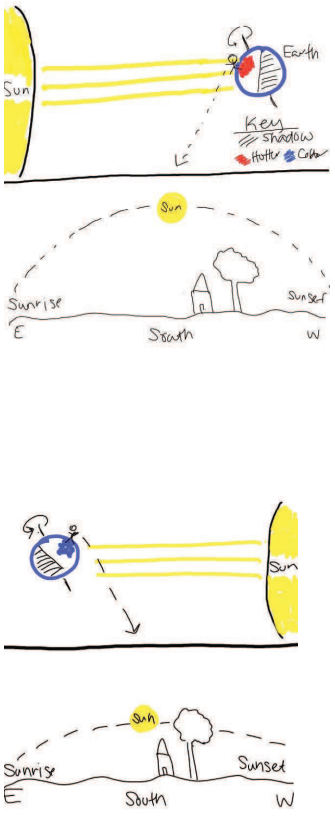
Record students' ideas in their Progress Trackers. Say, *over the last few lessons we've developed some really important ideas about seasonal patterns, like the motion of Earth around the Sun and temperature, both of which impact a lot of people and other living things on Earth. Let's keep track of some of these ideas in the Progress Tracker in our notebooks.* Display **slide J**.

Students should label the left side of the T-chart "Question/Lesson #" and the right side "What I figured out," as shown on the slide. Direct students to record the lesson question in the left column of the table, along with the lesson number. Then have students add their ideas in the right column. Remind them that they can use any combination of words and pictures to record their ideas. An example of what students might record is shown in the next table.

Additional Guidance

Remind students that the Progress Tracker is a thinking tool that is designed to help them keep track of their ideas. The sample Progress Tracker included in these materials serves as teacher guidance for what students might say at various points throughout the unit. Some students may say more, others may say less. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment. In this way, the Progress Tracker can be used to make visible individual student progress throughout the unit. When the class comes to consensus in future lessons, students will record this in their Progress Tracker with sources of evidence, making it clear that this is a classroom consensus model, not a record of individual thinking.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to me or my community or other communities?
How do these changes in sunlight impact us here on Earth?	Because of Earth's tilt, the sunlight shines on us directly when we are tilted toward the Sun. When it's like that, the Sun is high in the sky, like this. When the Sun is shining directly on us, the sunlight is more concentrated so it feels hotter. That's summer. When we are tilted away from the Sun, the sunlight is at an angle. When it's like that, the Sun is low in the sky, like this. When the Sun is shining at an angle and looks low in the sky, the sunlight is spread out so there will be less energy per area and it feels cooler. That's winter.	Answers will vary, but some sample ideas could include: • On days when the Sun is higher in the sky, we need to protect ourselves from getting sunburned. • In the winter the sun is bright in my eyes (it's lower in the sky) but it doesn't really warm me up outside.



6. Revisit the Lesson 1 podcasts.

4 MIN

Materials: None

Navigate to the assessment scenario to explain why there are seasons and why the seasons are different in the Southern Hemisphere. Display **slide K.** Say, *We've figured out a lot about the seasons we experience here, but have we heard about someone else's experiences in a different part of Earth? Look for students to point out that Jessie's podcast from Lesson 1 talked about different seasons in Australia.* Lead a short discussion to explain the difference in these patterns in the Southern and Northern Hemispheres, and make a connection back to the podcasts in Lesson 1.



Present **slide K**, which has the podcast map we saw in Lesson 1. Say, *In the podcasts we listened to in Lesson 1, we heard about how the seasons are actually the opposite in Australia and South Africa compared to our area.*

Replay or read part of *Reading - Podcast: Jessie Ferrari - Wombat Season*. Play the following portion of *Reading - Podcast: Jessie Ferrari - Wombat Season* and have students take notes on what they notice about Jessie's descriptions of the different seasons in Australia. Ask, *How does this happen? How are there different seasons? How are those seasons different in the Southern Hemisphere? Aren't we all on the same Earth and in the same position related to the Sun?*

Narrator: Jessie lives in Australia, which is in the Southern Hemisphere. That means the weather in Australia is warm when we experience cold weather and cooler when we feel the hottest temperatures of the year in the Northern Hemisphere.
Jessie: Generally, from the onset of September all the way to late Feb is when you'll get hot, warm, hot climate.
Narrator: We might call the time of year when the climate is hot, summer. But Jessie told us that the 4 seasons we are familiar with are not universal. For Jessie's communities, there are many more seasons than the 4 we are familiar with in our culture. Jessie shared how the stars in the sky help to mark the arrival of those seasons.
Jessie: We observe and keep track of the movement of stars in our sky. By looking at the placement at certain points, it helps us tell what seasons are coming, what weather to expect. So, you have around about 8 seasons, and they're all to do not necessarily with just the temperature and the climate but also with behavior of different animals and the coming of different plants and the behavior of stars in the sky. So, different constellations coming in and out, moving at different points in the sky, or depends on their brightness as well. We do have this one season among the Wurundjeri called the Waring, or Wombat season … this is around April–July. Wombats, you'll start to see emerge from their burrows to busk, which is like go around grazing and that sort of thing, and graze in the sunshine. And you'll also start to hear the mating courtship displays and calls of the Bullen Bullen, which is the Wurundjeri word for superb lyrebird. During the season, interestingly, the constellation of Sagittarius rises in the southeast after sunset, indicating the midpoint of cold weather. So, when it rises in the southeast, you can tell the cold weather is coming about. So, that's that connection to the sky but also to the behavior of the animals and the coming of food sources.

7. Create a Gotta-Have-It Checklist to explain differences in seasonal temperature and opposing seasons in different hemispheres.

12 MIN

Materials: science notebook, *Lesson 4 Gotta-Have-It Checklist*, chart paper, markers

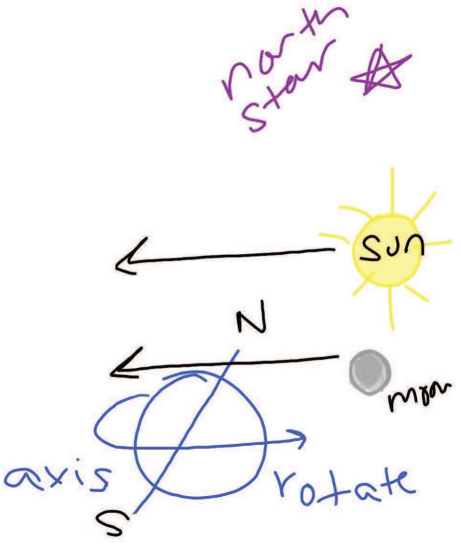
Preview the Gotta-Have-It Checklist. Explain to students, *You will create a Gotta-Have-It Checklist for everything we have figured out so far about why there are seasons on Earth. We will decide which ideas from our Progress Trackers and investigations are most important for explaining the differences in seasonal temperatures. You will use this checklist when you are taking the* What causes the seasons in Australia and why are they opposite of our seasons?. *First, consult the Progress Trackers in your notebooks to determine what is most important for explaining why there are seasons and how those seasons can be opposite depending where you are on Earth.**

*** Attending to Equity**
Having students select a personal norm for their work today will help reinforce to them that the class norms are important. This also creates an opportunity for students to actively participate in group work following norms and

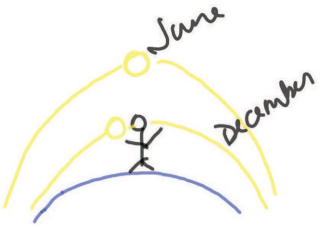
Create the Gotta-Have-It Checklist with a partner. Distribute a copy of *Lesson 4 Gotta-Have-It Checklist* to each student. This will be taped or glued into students' science notebooks when complete. Remind students how to build the checklist. Students will complete only the left column. They should leave the right column blank for now.

Give students 5 minutes to work with a partner to develop their checklists from important science findings recorded in their Progress Trackers that would help them answer the following: *Why are there seasons? How can those seasons be opposite depending on where you are on Earth?* Students should record the ideas they agree would help them answer this question on the checklist. They do not need to record all of the ideas from previous lessons—only the ones they want to include to answer the lesson question. Students should spend up to 5 minutes working with their partners.

Present **slide L** and ask students to open their science notebooks to models we made in our Progress Trackers from Lesson 3. Say, *Let's use our model and Progress Trackers to help explain why there are seasons and why it is winter in Australia when it is summer here.*



Look for students to point out that when the Earth is tilted toward the Sun in the Northern Hemisphere, the Southern half of the globe is actually pointed away from the Sun. So that when the Sun is directly above us, it is at an angle for people in South Africa and Australia, meaning that it will be cooler there when it is warmer here and vice versa.



Remind students of classroom norms, as necessary. Emphasize the importance of having a safe space where students can share their ideas and push one another's thinking. Highlight important ways to talk with one another, including frames for how to agree or disagree respectfully and how to push for justification. Encourage students that it's OK to share an idea they're not sure about or to disagree with someone's or a group's idea. Ask students to pick one of the classroom norms that they feel personally connected with to work on today. Say, *As we build the Gotta-Have-It Checklist, remember the process should be collaborative and involve students arguing from evidence for their ideas. We will create a public record of the ideas we agree are important.**

Facilitate a discussion to share ideas about what to include in the Gotta-Have-It Checklist. Spend up to 8 minutes allowing students to share what they included on their checklists. Ask students to briefly mention an idea they included on the checklist and why it's important. As you build the checklist as a class, have students add anything they are missing to their individual copy of *Lesson 4 Gotta-Have-It Checklist* , so they can use it on *What causes the seasons in Australia and why are they opposite of our seasons?*. If time permits, you can also ask which ideas they did not include and why those ideas are less important. The example student responses are not a comprehensive list of all the ideas. See the suggested prompts and responses for suggestions on what students might say.

to self-regulate their participation in group activity. Over time, these normreinforcing strategies can help build a positive group-work culture by encouraging students to identify the resources that can strengthen their group and systems to ensure that all students are actively participating in sense-making.

*** Supporting Students in Engaging in Developing and Using Models**

An alternative to doing the Gotta-Have-It Checklist in partners is to construct the checklist together as a class with a public representation of the ideas the class agrees should be part of the consensus model. If you make a modification to the current activity, keep in mind the following important components to make this activity a productive one: (1) the process should be collaborative and involve students arguing from evidence for their ideas, and (2) there should be a public record, or artifact, of the ideas students agree to include in their models.

*** Attending to Equity**

The sample Gotta-Have-It Checklist responses are suggestions for important ideas students will use to develop a model and construct an explanation later in the lesson. It is important, however, to appropriate the words and ideas that your students use and agree upon during this discussion.

Key Ideas

Purpose of the discussion: There are two goals of this discussion: (1) to generate ideas about why studying the sky is relevant for humans, and (2) to generate new ideas about specific patterns in the sky.

Listen for these ideas:

- Earth moves around the Sun, but even though the orbit is not a perfect circle, the distance between Earth and the Sun does not explain the seasons we experience.
- Because of Earth's tilt, the sunlight shines on Earth's surface more directly when we are tilted toward the Sun. When we are tilted away from the Sun, the sunlight is at more of an angle.
- When the Sun is shining more directly on the surface of Earth, the sunlight is more concentrated on that surface, which warms it up, so it feels hotter. That's summer. When the Sun is shining at more of an angle and looks low in the sky, the sunlight is spread out over more surface so those surfaces don't warm up as much and it feels cooler. That's winter.
- When the sunlight is direct on the top half of Earth (the Northern Hemisphere), it is at a lower angle in the sky in the Southern Hemisphere, and vice versa. This is why the seasonal patterns are the opposite for us compared with places like Australia and South Africa.
- Because of Earth's tilt, the amount of daylight hours increases when we are tilted toward the Sun and decreases when we are tilted away from the sunlight. This also results in less energy reaching the surface during the winter, and more reaching during the summer. This also contributes to why those surfaces don't warm up as much in winter and it feels cooler in that season. The season pattern for when this happens is also the opposite of us in places like Australia and South Africa.

Suggested prompt	Sample student responses
*Can someone suggest an idea we've figured out about the Earth-Sun system from Lessons 1–4 that will help us explain why there are seasons and why those seasons are opposite in some places on Earth?**	*The Earth moves around the Sun, but even though the orbit is not a perfect circle, the distance between the Earth and the Sun does not explain the seasons we experience.* *Because the Earth is tilted, sometimes the sunlight shines on us directly, when we are tilted toward the Sun. Other times the sunlight is at an angle, when we are tilted away from the Sun.* *When the sunlight is direct on the top of the Earth (the Northern Hemisphere), it is at an angle in the Southern Hemisphere, and vice versa.* *When the sunlight is directly on the top of the Earth (the Northern Hemisphere), the number of daylight hours is longer, this is when the number of daylight hours is shorter in the Southern Hemisphere, and vice versa.*

Your class's list of ideas could be articulated differently and may include other ideas not listed here. Actively look for different ways students share and represent their ideas (e.g., words or pictures) as an opportunity to communicate to your students that different ways of representing their thinking is valuable.

Assessment Opportunity

Building towards: 4.B Develop and use models of the Earth-Sun system to explain the cause-and-effect relationships between Earth's tilt, solar elevation, and sunlight energy on Earth's surface to explain seasonal temperature differences.

What to look/listen for: Use the partner and whole class discussion as a formative assessment moment before students take the individual assessment. Look for the way that students are describing how the tilt affects the temperature. It is common for students to combine their ideas about proximity and warmth with the new ideas about the tilt of Earth to form a hybrid conceptual model. Students who are using this conceptual model will explain that the tilt of Earth pushes one hemisphere closer to the Sun in summer.

What to do: If you hear this idea come out, highlight it and ask, *Is that what is happening? Does anybody else have a different idea?* Ask students to go back to the evidence from the investigation and explain how those data support this idea. The difference in distance due to the tilt of Earth between the two hemispheres is negligible compared to these numbers. Make sure the class comes to consensus that while, in general, proximity does affect how much energy we get from something, in this case, the *concentration* of the light is the primary driver of temperature patterns.

8. Demonstrate understanding on an assessment task.

20 MIN

Materials: science notebook, *What causes the seasons in Australia and why are they opposite of our seasons?*, *The Equator, the Midnight Sun, and the Analemma* (optional), Patterns and Phenomena in the Sky poster (optional)

Prepare for *What causes the seasons in Australia and why are they opposite of our seasons?*. Display **slide M.** Ask students to make sure they have *Lesson 4 Gotta-Have-It Checklist* easily accessible.

Additional Guidance

Remind students that they are free to use the physical modeling supplies from Lessons 3 and 4 during the assessment.

Administer *What causes the seasons in Australia and why are they opposite of our seasons?* to students to work on individually. This should take students 20 minutes to complete.*



Assessment Opportunity

Building towards: 4.B Develop and use models of the Earth-Sun system to explain the cause-and-effect relationships between Earth's tilt, solar elevation, and sunlight energy on Earth's surface to explain seasonal temperature differences.

What to look/listen for: See *What causes the seasons in Australia and why are they opposite of our seasons?* for guidance.

What to do: If students are struggling to clarify their thinking around the different spatial cause-and-effect relationships of the position of the Sun and Earth for seasons at different locations on Earth, allow them to use the physical modeling supplies. Let them manipulate the Earth and Sun with you and begin by explaining verbally. Then encourage them to write or draw their thinking on paper.

*** Attending to Equity**

This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so far through multiple modalities, including writing to explain and drawing models. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models. Some students might also benefit from using manipulatives to represent parts of the model

Offer an optional extension reading if students finish early, or send it as home learning. Display **slide N.** Say, *The tilt of Earth as it orbits the Sun explains a lot of different patterns that we experience on Earth. Some of them we experience here in the Northern Hemisphere, and some of them we need to travel in order to experience.* Offer students *The Equator, the Midnight Sun, and the Analemma* as an optional extension reading about other things we can explain with this model, including the midnight Sun and the annalema. This reading is also available as a handout.

and to support a written or verbal explanation of what's happening in each part of the model. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

Alternate Activity

Extension opportunity: *The Equator, the Midnight Sun, and the Analemma* provides additional information to students that is not critical to their understanding of the DCIs in this unit, but is offered as a chance for interested students to dig a little deeper into the patterns people notice about the Sun's apparent movement in the sky. As such, students may choose to read just certain sections of the text that they find most intriguing. If students do not all get a chance to read this text, you might ask a few students to share with the class what they found out from reading in order to collect additional ideas on the Patterns and Phenomena in the Sky poster.

9. Navigation

5 MIN

Materials: None

Next steps. Display **slide O.** Motivate trying to see if the ideas we included on our Gotta-Have-It Checklist and assessment could also explain something other than the seasons.

Suggested prompts	Sample student responses
Now that we have figured out a few things about how the position of the Sun and Earth determine the seasons, do you think we could use this to explain other patterns we see in the sky?	*Yes!*
Do you think we could explain Manhattanhenge?	*We think we could explain Manhattanhenge.*
What else from our related phenomena might we be able to explain using what we have figured out about the position of the Sun and Earth?	*Accept all answers that are tied to something on the Phenomena and Patterns in the Sky poster.*

Navigate to the next lesson. Say, *It sounds like we think that we can use what we have figured out about the seasons and the position of the Sun and Earth to explain other patterns in the sky. Let's try it and see if you can use our Gotta-Have-It Checklist to explain the Manhattanhenge phenomenon.*

ADDITIONAL LESSON 4 TEACHER GUIDANCE

Supporting Students in Making Connections in Math

CCSS.MATH.CONTENT.7.RP.A.1 Compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units. *For example, if a person walks 1/2 mile in each 1/4 hour, compute the unit rate as the complex fraction 1/2/1/4 miles per hour, equivalently 2 miles per hour.*

In this lesson, students calculate the ratio of light per unit area to solve a real-world problem: explaining temperature variation over a year.

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

In this lesson, students have multiple opportunities to read texts to find answers to some of their related questions (which will require them to determine central ideas in those texts) about seasons and the patterns of the Sun in the sky. When possible, students are encouraged to share what they've learned from the texts with their classmates and/or other trusted people (which gives them a chance to authentically summarize the text in order to support discussion about these ideas).

SCIENCE LITERACY: READING COLLECTION 1

Sky Watching Since Days of Old

1 **Celestial Stories**
2 **Archimedes's Mirror**
3 **Make Your Own Sundial**
4 **Around the World, Across Time**

Literacy Objectives

- ✓ Summarize key points related to ancient attempts to understand observations of the sky.
- ✓ Organize details related to discoveries, stories, and inventions.
- ✓ Translate text to visual/graphic representation of ideas.

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 1: How are we connected to the patterns we see in the sky?
- Lesson 2: What patterns are happening in the sky that I have experienced and can observe (through models and tools)?
- Lesson 3: How can we explain the Sun's path change over time?
- Lesson 4: How do these changes in sunlight impact us here on Earth?

Instructional Resources

Student Reader



Collection 1

Science Literacy Student Reader, Collection 1
"Sky Watching Since Days of Old"

Exercise Page



EP 1

Science Literacy Exercise Page
EP 1

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 1–4.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a concept map in response to the reading.

Standards and Dimensions

NGSS

Disciplinary Core Ideas ESS1.A: The Universe and Its Stars Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

PS4.A: Wave Properties The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)

Science and Engineering Practice: Planning and Carrying Out Investigations

Crosscutting Concept: Connection to Nature of Science

CCSS

English Language Arts

RST.6-8.2: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6–8 text complexity band independently and proficiently.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

orbit **reflect** **refract**
celestial

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

focal point **reflecting telescope**
refracting telescope **zodiac**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Earth in Space unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you'll read five brief stories from ancient cultures that explain the appearance of objects in the sky.*

- *Next, you'll read a tale about the ancient Greek mathematician, scientist, and engineer named Archimedes. Is the story true? Probably not, if you analyze the science involved.*
- *Then, you'll read directions for constructing your own sundial and using it to tell time.*
- *Finally, you will interpret a map of the world annotated with some first-known discoveries and inventions related to Earth in space.*

- Distribute Exercise Page 1. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a concept map to summarize the readings in Collection 1. Your map will show examples of three ways humans have attempted to explain what they see in the day and night skies.*

Exercise Page



EP 1

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What characteristic of Archimedes's mirror made it able to focus light?	*The mirror was curved.*
How does the sundial procedure say to angle the drinking straw?	*It says to point it slightly toward the north pole if you are in the Northern Hemisphere and toward the south pole if you are in the Southern Hemisphere.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What changing sky pattern does the Norse story about two wolf pups help people recognize?	*how the sun moves across the sky each day and the moon moves across the sky each night*
How would you draw the light rays in the story about Archimedes?	*straight lines from the sun to a curved mirror, then straight lines in new directions from the mirror to the ship* *also, straight lines from the ship to a viewer's eye*
What patterns of Earth in space are related to a working sundial?	*Earth turning on its axis* *the sun appearing to move across the sky during the day* *changes in the lengths of shadows* *the changes in the sun's elevation above the horizon* *Although the tilt of Earth's axis is always the same, it causes different parts of Earth to receive different levels of the sun's intensity over the course of a year.*
What two types of telescopes were invented in the 1600s?	*refracting telescopes and reflecting telescopes*

- Refer students to the Exercise Page 1. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a concept map to show examples of three ways humans have tried to explain what they observe in the day and night skies.*
  - *You'll find details in all four reading selections that you can use to complete your map.*
  - *First try to fill in parts of the map from memory. Then, if you get stuck for ideas, go back and review the readings.*
  - *At a minimum, your concept map should have as many details as the template shows. You are also welcome to add more details to your map.*
  - *The important criteria for your work are that your map is drawn carefully enough that others can interpret it and that it accurately categorizes details from the readings as stories, discoveries, or invention of tools.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 1

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. Students begin the reading activity by interpreting an annotated map showing some of the earliest known human efforts to understand and explore the sky and space. Tell students to notice how contributions to understanding Earth in space have been made over long periods of time by people in many different cultures.

Student Reader



Collection 1

Pages 4–13 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Celestial Stories"?	*It summarizes some of the stories told by ancient peoples to explain things they saw in the sky, such as lunar eclipses, the movement of the sun in day and night, and star constellations.*
Myths can be read to learn what ancient peoples thought about patterns in the sky, but they are also a form of literature. People read literature to feel what it was like to be in a certain place and time, to guide their thinking about what is right and wrong, and for fun and enjoyment. Which of these ancient stories did you enjoy the most and why?	*I enjoyed the story called "The Moon Rabbit" because the rabbit was heroic. But it was sad that she had to die to save the life of someone else.* *The story "The Seven Boys and the Pines" was fun to read because it reminded me of my friends and how we don't like to stop playing sports or video games to go have dinner.*
What is the general purpose of the second article, "Archimedes's Mirror"?	*It explains why the old story about Archimedes using a mirror to burn up enemy ships is not likely to be true.*
What does "focal point" mean in this context, and why is it important?	*Light beams are made up of lots of individual light rays. Each one travels in straight lines. Since the rays are bouncing off a curved surface, each ray goes in a slightly different direction. The focal point is where all the rays cross. This is where there might be enough energy to start a fire.*
What would Archimedes have to know about the sun in the sky in this scenario?	*that the sun is only shining certain hours of the day* *that the sun's energy is most intense when it is highest in the sky*
What is the general purpose of the third article, "Make Your Own Sundial"?	*It describes the materials and procedure for making a model sundial that works to tell time.*
There are lots of science projects, science fair ideas, and science investigation ideas online. How do you know which ones are reliable and which ones to avoid?	*Choose from websites that are educational, from organizations of scientists, or from government websites, and avoid personal sites or sites that seem out of date or poorly written.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

EXTEND—The story of the Pleiades describes six boys plus one more who never made it into the sky. Using the unaided eye, most ancient peoples could only see six stars in this constellation. However, astronomers have evidence that a seventh star varies in brightness and could sometimes be seen. This is likely the phenomenon that the Cherokee alluded to in the story of the seven boys. Students may enjoy learning more about the Pleiades star cluster on a variety of reliable websites.

Pages 4–13 Suggested prompts	Sample student responses
Let's say you wanted to use this sundial to know when it is time for school dismissal each day. How would you do it?	*Go outside a little before dismissal time, and make a mark on the clock where the shadow falls at the exact time school is dismissed. Then the next day, watch the shadow, and when it gets very close to that mark, you'll know it's time for dismissal.*
Take a look at the questions in the "Connection" box. Does the shadow move clockwise or counterclockwise around the plate? Why?	*The shadow moves clockwise around the plate as the sun moves from east to west in the sky.*
How might you modify the sundial to tell the minutes in addition to the hours?	*Use the clock to note when it is, say, half past the hour, and mark the sundial where the shadow falls. This should be about halfway between one hour mark and the next hour mark.*
What would happen if you moved the sundial from the spot where you made it?	*If you hold a compass and move far enough, the compass needle will move a little to keep pointing north. So, you would have to set up a moved sundial using the compass again.*
What is the general purpose of the fourth selection, "Around the World, Across Time"?	*It describes the place, year, and other details about discoveries and inventions related to space, from ancient times almost to the present.*
What was one "first" that surprised you? Why?	*I was surprised that someone living 2,500 years ago figured out how eclipses occur. I thought that, in those days, people believed the sky was a flat surface and that all moons and stars were the same distance from Earth.*
Think about the concept map you drew. Which of the three categories of examples could you add to after reading this selection?	*All three!*
Take a look at the "Connection" box. Why might records of other discoveries and inventions have been lost or destroyed?	*The records could have been made on materials that weather or decompose.* *The record might have been an oral history that was forgotten.* *Someone might have never shared their invention with others.*

CHALLENGE—Some students may enjoy the challenge of making a sundial without using a clock. To do so, they might watch the sky over several days to approximate when the sun reaches its highest point in the sky and casts the shortest shadow on the plate (12 p.m.). Looking up the times at which the sun rises and sets on the dates they are observing and making inferences will help mark the other times on the sundial.

SUPPORT—English learners may need support in understanding the abbreviations *BCE* and *CE* and wonder how they compare to *BC* and *AD*. Explain that while many news sources follow the latter style, in which *BC* stands for "Before Christ" and *AD* stands for "*Anno Domini*" (in the year of our Lord), most scientists refer to the recent 2,020 or so years as "Common Era" and years before this time as "Before the Common Era."

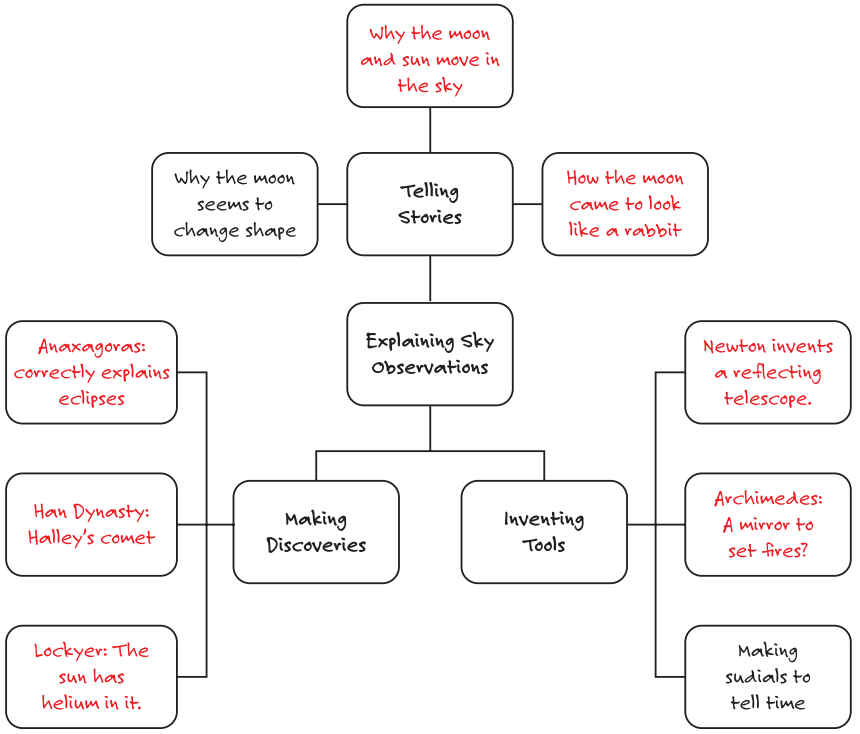
EXTEND—The James Webb Space Telescope was launched in late 2021. Have students do online research to answer questions about this project, such as: What do scientists hope to learn with this telescope? What wavelengths of light was the Webb telescope designed to detect? What are some of the essential parts of this space telescope and their functions?

Pages 4–13 Suggested prompt	Sample student responses
How does this selection build on a theme of the first selection?	*The map in this selection shows that people from all over the world and many cultures contributed to understanding Earth in space.* *If you were to mark the map to show the sources of the stories in the first selection, you'd see that people all over the world thought patterns in the sky were important to explain.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 1, students should, from a partially completed template, complete a well-constructed concept map to summarize Collection 1. Students will need to understand the organization of the map and then add supporting examples for each of the three categories. A sample completed concept map is shown below, but students may cite other examples from the readings.



LESSON 5

How can we explain phenomena like Manhattanhenge?

Previous Lesson

We analyzed seasonal temperature data from two cities in the United States and argued that changes in Earth's distance from the Sun do not explain seasonal temperature differences. We developed a physical model and used it to collect data on changes of sunlight energy on Earth's surface as a result of changes in solar elevation. We wondered if this model also helps explain seasonal temperature differences in other parts of the world. We developed a Gotta-Have-It Checklist and completed an assessment applying our models to another location on Earth.

This Lesson

Putting Pieces Together, Problematizing

1 DAY



We use a video simulation to investigate patterns we think might be responsible for Manhattanhenge. We revise a model of the Manhattan solar phenomenon. We revisit the Driving Question Board to connect what questions we have answered and what questions remain. We decide to make observations of the Moon.

Next Lesson

We will use a physical model and an online interactive to help make sense of the positions of the objects in the Earth-Sun-Moon system that cause us to see the current shape of the Moon. We will also use our physical models to predict the next phase of the Moon.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

5.A Develop and use a model of the Earth-Sun system to explain how Earth's fixed tilt and orbit would cause a cyclical pattern in the location of the Sun at sunset that repeats every year.

What Students Will Figure Out

- The light rays from the Sun at sunset follow a straight path that happens to align down many streets between the buildings on either side in Manhattan only 2 times a year.

- There is a reversal (symmetry) in the pattern of change in where the Sun sets (and rises), day length, and the angle of the Sun in the sky that occur between the summer and winter solstice.
- The fixed tilt of Earth's axis and its orbit around the Sun causes this reversal in these patterns of change between the two extreme points in its orbit, in terms of how much the Earth's tilt is pointed toward the Sun (summer solstice and winter solstice).

Lesson 5 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION**	A-D	
2	8 min	**INVESTIGATE PATTERNS WE BELIEVE ARE RESPONSIBLE FOR MANHATTANHENGE** Students watch a video from a simulation of the Sun's path throughout the year in New York to see if they can explain why Manhattanhenge occurs.	E	*Connecting Patterns in the Sun to Manhattanhenge*, www.stellarium.org, 8.4 Lesson 5 Using Stellarium for Manhattenhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	15 min	**DEVELOP A CONSENSUS MODEL ABOUT HOW THE MANHATTANHENGE HAPPENS TWICE A YEAR**	F-H	*Self-Assessment for Classroom Discussions*, Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon poster, chart paper, Classroom Consensus Model of Manhattanhenge, markers
4	7 min	**PROBLEMATIZE OTHER RELATED PHENOMENA**	I-J	sticky notes
5	5 min	**RETURN TO THE DQB** Revisit the Driving Question Board and re-anchor where we are going based on our questions and what we have figured out so far.	K	sticky notes, markers, DQB
6	4 min	**NAVIGATION AND HOME LEARNING**	L	*Lesson 5 Community Guide for Looking at the Sky*, DQB

End of day 1

Lesson 5 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Connecting Patterns in the Sun to Manhattanhenge* • www.stellarium.org • 8.4 Lesson 5 Using Stellarium for Manhattenhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Self-Assessment for Classroom Discussions* • sticky notes • markers • *Lesson 5 Community Guide for Looking at the Sky*		• Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon poster • chart paper • Classroom Consensus Model of Manhattanhenge • markers • DQB

Materials preparation (5 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Using Stellarium for Manhattanhenge video 8.4 Lesson 5 Using Stellarium for Manhattenhenge ahead of time. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Make sure students have access to their *Initial Manhattanhenge Model* or can locate the page in their science notebooks.

Make sure the class can publicly view the Driving Question Board and the Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon poster.

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Classroom Consensus Model of Manhattanhenge: You can draw most of this poster ahead of time. The positions of Manhattanhenge #1 and Manhattanhenge #2 could be added with index cards or half sheets of paper and string to allow them to be removed between classes, but the underlying base model will be familiar to students based on the work they did in Lessons 2 and 3.

Lesson 5 • Where We Are Going and NOT Going

Where We Are Going

This lesson provides an opportunity for students to revisit key ideas by taking stock of ideas learned in Lessons 1–4. In this lesson, students revisit their initial models of the Manhattanhenge phenomenon from Lesson 1, investigate patterns in the Sun that might be connected to Manhattanhenge, and use those patterns to co-construct a consensus model of the parts and interactions in order to cause people to be able to see it on just two days of the year.

Students revisit the Driving Question Board and utilize the ideas we developed in prior lessons to answer select questions from the beginning of the unit before navigating to unanswered questions about the Moon. This is the last lesson that focuses solely on patterns in the Earth-Sun system and is the end of the first lesson set of the unit.

Where We Are NOT Going

Here at the end of this first lesson set, students have only investigated the relationship between the position of the Sun, the stars, and Earth and what they see. Students have not yet begun to organize the other parts of the solar system. We will add an additional scale and perspective to our understanding of the role of gravity in causing the relatively stable orbits of the parts of the solar system as well as organizing the parts of the solar system during its formation. In Lesson 4, when we add a galactic scale to our system models. Furthermore, students have not yet conducted investigations to explain patterns in the sky related to color changes (e.g., the Sun at sunset). This will happen in Lesson 3, after adding the Moon to their systems model of the Earth and the Sun in Lesson 6 and 7.

LEARNING PLAN FOR LESSON 5

1. Navigation

6 MIN

Materials: science notebook

Remind ourselves of what we've figured out so far in the unit. Present **slide A**. Have students open their science notebooks to flip through their investigations and Progress Tracker. Say, *Can someone remind us why some places in the Southern Hemisphere experience their seasons at the opposite time of year compared to places in the Northern Hemisphere?* Look for students to respond as follows:

- The temperature differences can be explained because the angle of the Sun's light rays result in the energy being less spread out where it's warmer and more spread out where it's colder.
- The angle of the Sun's light rays are different because Earth is tilted toward a fixed point in the sky (the North Star) and spinning on its axis as it orbits the Sun.

Additional Guidance

If students struggle to recall how our new understanding can help us explain temperature differences on Earth, prompt them to look back at their Progress Trackers.

Show **slide B.** Ask, *Last time we identified some additional phenomena that we said we could explain with the same model. What were some of those phenomena?* Look for students to suggest that we could explain Manhattanhenge or other phenomena that include repeating patterns of the Sun's position in the sky. If students don't raise this example, you can follow-up by asking, *do you think we could use our model to explain the Manhattanhenge phenomena?*

Return to the Manhattanhenge Phenomenon. Present **slide C.** Discuss what patterns students notice about the two times Manhattanhenge occurs. And then work with students to identify the number of days between these two occurrences and what students recall about how the day (and path of the Sun) is changing over this period of time during this part of the year.

Suggested prompts	Sample student responses
What patterns do you notice about when Manhattanhenge occurs?	*It tends to occur at around the same two times every year:* • *May 30th, and* • *July 11th or July 12th.*
About how many days pass between the first occurrence and the second occurance in the year?	*about 40 to 42 days*
What do we recall about how the day changes over this part of the year?	*Accept all responses. These may include things about day length and path of the Sun in the sky and when the longest day of the year is.*

Additional Guidance

Students might point out that Manhattanhenge occurs 4 times a year, twice for sunset and twice for sunrise, which is sometimes called reverse Manhattanhenge. It happens on different dates around either side of the Winter Solstice and looking east as opposed to looking west.

Suggested prompt	Sample student responses
Can someone remind me what is interesting about what people observe on the days when Manhattanhenge occurs? What is it about their observations that we need to be able to explain?	*The Sun is setting on the horizon directly in between buildings.* *The grid system is north-south, so the streets face east-west.* *The Sun is setting on the west side of New York.* *We need to be able to see the Sun setting.*

Make predictions. Ask students to consider what pattern we would expect to see where the Sun is setting on the horizon in New York between both days of the year Manhattenhenge tends to occur. Show **slide D**. Give students a minute to discuss this question with a partner, then have them share out as a whole class. Accept all predictions.

Say, *Let's return to that simulation to check our predictions and see if we notice anything interesting in these patterns of the Sun before, during, and after both times Manhattanhenge occurs to see if we can use our model of what is happening with the Earth and the Sun over the course of the year to explain what is happening!*

2. Investigate patterns we believe are responsible for Manhattanhenge. 8 MIN

Materials: *Connecting Patterns in the Sun to Manhattanhenge*, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), 8.4 Lesson 5 Using Stellarium for Manhattenhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Play 8.4 Lesson 5 Using Stellarium for Manhattenhenge (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Display **slide E.** Or alternately allow students to either play 8.4 Lesson 5 Using Stellarium for Manhattenhenge themselves or manipulate the Stellarium website themselves to look for patterns and complete *Connecting Patterns in the Sun to Manhattanhenge* (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). If you do the latter, demonstrate first how to center the location of the observer in New York.

You will collect *Connecting Patterns in the Sun to Manhattanhenge* after class as an individual assessment for connecting Manhattanhenge to the cause of repeating similar patterns of the Sun's position in the sky, after the classroom consensus model.

3. Develop a Consensus Model about how the Manhattanhenge happens twice a year. 15 MIN

Materials: science notebook, *Self-Assessment for Classroom Discussions*, Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon poster, chart paper, Classroom Consensus Model of Manhattanhenge, markers

Develop a Gotta-Have-It Checklist to explain Manhattanhenge. Display the *Parts & Interactions in the System That Help Explain the Manhattanhenge Phenomenon* poster from Lesson 1. Present **slide F**. Say, *Let's look back at the parts and interactions in the system that we used previously to help explain the Manhattanhenge Phenomenon poster and consider what we might want to add to it or change in light of all that we have figured out about the Earth-Sun system over the previous few lessons*. Tell students to turn and talk with a partner to evaluate what parts and interactions still work and what ones we need to change based on our new understandings. Give students a few minutes to discuss with their partners and then a few students to share what they discussed.

Create classroom consensus model of Manhattanhenge. Present **slide G** and move into a Scientists Circle**.** Work with the class to develop a class consensus model on a piece of chart paper. Use probing questions such as those below and on the slide:

- *What parts should we include on our class consensus model?*
- *What interactions should we include on our class consensus model?*

*** Attending to Equity**

Universal Design for Learning: This is a great opportunity for students to self-assess their *engagement* in classroom discussions using *Self-Assessment for Classroom Discussions*. This discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day.

Key Ideas

Purpose of this discussion: Come to consensus about how the repeating patterns of the Sun's position in the sky and particularly at sunset, based on the fixed tilt of the Earth on its axis and orbit around the Sun, could cause the Manhattanhenge phenomenon to occur year after year around the same day and why it would occur twice a year.

Listen for these ideas

- *Sun*
- *Earth*
- *Earth's axis*
- *Buildings*
- *The Sun sets and rises at certain points in the sky because of Earth's location in our orbit around the Sun.*
- *Earth's tilt can explain why the path of the Sun changes during the year.*
- *Earth's orbit around the Sun produces reverse symmetry in the pattern of how day length and path of the Sun change over the course of the year. That symmetry is related to the summer and winter solstice.*
- *When the Sun's path lines up between the buildings two times a year, Manhattanhenge occurs.*
- *This occurs at about the same length of time away from the summer solstice (22 days away from it, which occurs on June 21st, the longest day of the year), and this would correspond to equal distance from the same point in Earth's orbit when the tilt of the Earth in the Northern Hemisphere is most directly facing the Sun.*

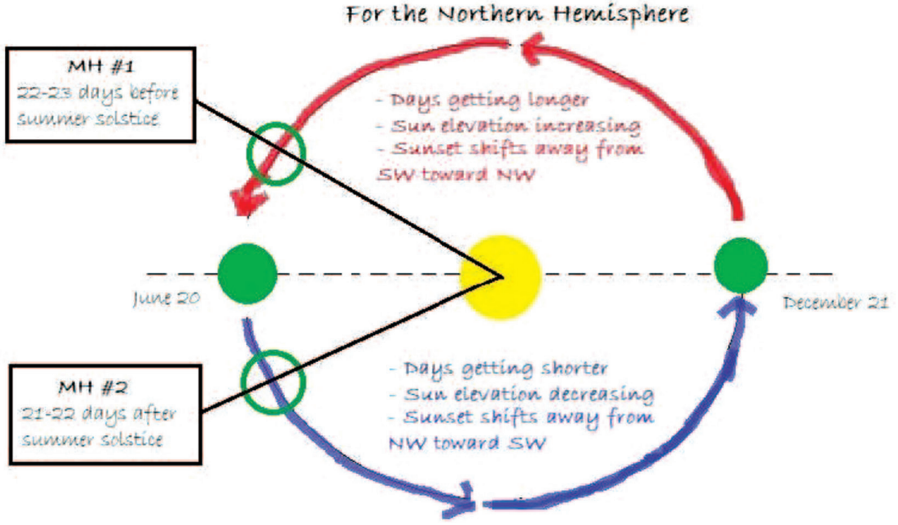
A sample class consensus model can be seen in the following images.

First yearly occurrence on May 30th: 22 days before the longest day of the year [summer solstice on June 21st]



Second yearly occurrence on July 11th or 12th: 21 to 22 days after the longest day of the year [summer solstice on June 21st]





Present **slide H** and have students answer the 4th question on *Connecting Patterns in the Sun to Manhattanhenge* to respond to the prompt, *Use the class consensus model to explain why Manhattanhenge occurs during certain times of the year.* Collect *Connecting Patterns in the Sun to Manhattanhenge*.

Assessment Opportunity

Building towards: 5.A Develop and use a model of the Earth-Sun system to explain why Earth's fixed tilt and orbit would cause a repeating pattern in the location of the Sun at sunset.

What to look/listen for: Student explanations should include the following:

- Ideas about how the fixed tilt of Earth's axis and its orbit around the Sun causes the location of sunrise and sunset to change in one direction during one half of the year and change back (reverse) in the other direction during the second half of the year.
- Identifying that an important point in the symmetry in when the patterns in the path of the Sun reverse is the summer (or winter) solstice and that this corresponds to when the tilt in the Northern Hemisphere of the Earth is most facing toward the Sun (or most facing away from it).

Students may also mention how these changes in where the sunset (and sunrise) occur correspond to changes in the path of the Sun and angle of the Sun in the sky (solar elevation) during the year.

What to do: If students do not identify that there is symmetry in the patterns of the day length or solar elevation as a result of fixed tilt and orbit of the Earth, refer them to look at their Progress Trackers from Lesson 4 or *Modeling Sunlight Angles*. If students do not identify changes in the location of sunrise or sunset as a result of this as well, refer them to look at *Modeling the Earth–Sun System*.

Discussion Self-Assessment. If time permits, distribute *Self-Assessment for Classroom Discussions* to students and have them fill it out on their own. After students complete *Self-Assessment for Classroom Discussions*, have them pick one thing they would like to work on in upcoming discussions and share that with a partner.*

4. Problematize other related phenomena. 7 MIN

Materials: science notebook, sticky notes

Problematize why Manhattanhenge occurs on different dates. Present **slide I**. Give students a few minutes to turn and talk about the question on the slide.

Suggested prompts	Sample student responses
When is the next year after these that you would expect the 2nd occurrence of Manhattanhenge to occur on July 11?	*2024*
How did you make your prediction?	*It was four years apart in the past, so it probably will be four years apart in the future.*
What question does this raise for you?	*Does the change in date actually repeat every four years?*
Why do you think it was a different date in July 2016 and 2020? and why might it repeat again in 2024, four years later? What is special about those years?	*They are presidential election years.* *They are leap years.*

Suggested prompts	Sample student responses
This shift in dates is due to something called a leap year, which is something that happens every four years. It is a year when we add an extra day to our calendars. Where else have we heard of a civilization having to change their calendar to account for more days?	*In Thembe's podcast, he said that they needed to add an extra 11 days to their calendar that used the Moon.*
So, in two cases, we need to periodically add extra days to our calendars. What interaction must be happening in the Earth-Sun system over time for us to need to add an extra day to our calendar?	*Maybe it takes a little longer than a year to travel around the Sun.* *If we have to add a day to our year, every four years, then that must mean our orbit takes longer than 365 days each year.*
What other questions do you still have about Manhattanhenge or similar phenomena?	*Accept all student responses.*

Say, *Let's go back to the DQB and add some of these questions and see what other questions we still haven't answered about other similar phenomena and patterns in the sky that may involve objects doing similar or different things.*

Generate new questions for the DQB. Display **slide J** and have students write down new questions they are now thinking about. Students should write down one or two questions on sticky notes with large, bold writing so that everyone can see. Remind students to write only one question per sticky note. Ask students to briefly share their questions with a partner.

5. Return to the DQB.

5 MIN

Materials: sticky notes, markers, science notebook, DQB

Return to the DQB. Display **slide K.** Give students a few moments to add any new questions to the DQB. Say, *Wow we really figured out a lot about the Sun!* If you didn't remain in the Scientists Circle for the previous part, move into the Scientists Circle now, around the DQB. Have student pairs identify a sticky note that they feel we have answered about the Sun or stars. Then ask them to turn and talk with their partner about the answer to the question on the sticky note.

If time permits, consider having students put the answered sticky notes in a new section of the DQB, or on a new piece of chart paper, with the answer written next to it on a bigger sticky note or piece of paper, or you might ask students to copy down the question in their notebooks and answer it underneath.*

*** Supporting Students in Engaging in Asking Questions and Defining Problems**
Revisiting the DQB helps students track the class's progress toward answering questions that were important to them. This helps build and sustain student buy-in, keeps learning relevant to students, and can generate new questions that may continue to motivate new directions to pursue.

6. Navigation and Home Learning

4 MIN

Materials: *Lesson 5 Community Guide for Looking at the Sky*, DQB

Navigate to the next lesson. Point to the DQB and say, *We still have a lot of questions about other objects in the sky. Turn to a partner and share a question to identify one or two other objects in the sky that we still have a lot of questions about.* Connect back to models from previous lessons. Say, *In our Lesson 2 and 3 models, we showed multiple objects moving across the sky. We can explain a lot about how the Sun is moving across the sky during the day and the stars that move across the sky at night, but what is one other object that appears to move and change across the sky that we should try to explain in our system next, based on the number of questions we have about?* Listen for students to make comments about the Moon.

Say, *Let's move onto this area about the Moon you have identified. We still have a lot of unanswered questions about it. The Moon is another thing that's easy to see with our unaided eyes, so we can document what we notice about it outside school.*

Prepare for Home Learning. Present **slide L**. Say, *I think this is a great idea. Let's all do what we can to observe the shape of the Moon before we meet next time. You can record your data by taking a photo, sketching a picture, describing the Moon in a paragraph, or looking at images of the Moon online.*

Distribute *Lesson 5 Community Guide for Looking at the Sky* to each student. This is very similar to the home learning from the end of Lesson 1, but this time we are focusing more specifically on changes in the Moon. *Say, Are there specific things about the Moon that we can observe in real life?* Look for students to suggest looking at the shape and color of the Moon, or even just looking up at the Moon and drawing it. Let's take some observations over the next few days and nights. *Be ready to share your observation, and describe when you took it, and where you were.* To make this easier for students, make sure that you have looked up the time of the moonrise and moonset beforehand so that you can tell them when to go outside and look for the Moon. An online lunar almanac or ephemeris will tell you when the Moon rises and sets today and over the next few days.

Alternate Activity

If students can't see the Moon because it is not safe for them to make observations outside or because the sky is obscured by buildings or weather conditions, you can use this time to ask if any students have seen it in the past. You can also print out a lunar calendar from an online ephemeris such as the Moonrise and Moonset Calculator to provide for students (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Students can check the phase of the Moon on their smartphones, if available, or using a search engine connected to the internet.

LESSON 6

Why do we see the shape of the Moon change?

Previous Lesson

We investigated patterns we think might be responsible for Manhattanhenge. We revised a model of the Manhattan phenomenon. We revisited the Driving Question Board to connect what questions we have answered and what questions remain. We decided to make observations of the Moon.

This Lesson

Investigation

2 DAYS





NASA's Scientific Visualization Studio

We look at the current shape of the Moon and historic representations of the Moon from cultures around the world, establishing that the Moon does not always look the same. We make an initial model to try to explain why we see the current phase of the Moon, and then we use a physical model to help make sense of the positions of the objects in the Earth-Sun-Moon system that cause us to see the current shape of the Moon. We also use these models to predict the next phase of the Moon. We use an online interactive to help us explain how changes in the position of the Moon affect the shape of the Moon we see.

Next Lesson

We will watch a video of a solar eclipse and then explain what we saw using a physical model of the system. After using a drawn model of a solar eclipse, we will return to our physical models to figure out when we might expect to see a solar eclipse.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2



What Students Will Do

6.A Develop and use a model of the Earth-Sun-Moon system to explain and predict patterns we observe in the way the apparent shape of the Moon changes over time.

What Students Will Figure Out

- People have watched the Moon across time and cultures.
- Light from the Sun shines on only half of the Moon.
- The shape of the Moon we see from one day to the next is a result of its position in space relative to Earth; the appearance of the shape of the Moon that we see on any particular day can be explained in terms of how much of the sunlit side we can see at that time.
- We can see the Moon at different times of the day and night.

Lesson 6 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**NAVIGATION AND SHARE HOME LEARNING** Revisit the home learning in which students made observations of the Moon's current appearance.	A-B	completed *Lesson 5 Community Guide for Looking at the Sky*, space to draw a quick sketch of the Moon
2	5 min	**CONNECT TO HUMANS ACROSS CULTURE AND TIME** View images documenting the Moon from different cultures and timescales.	C-D	
3	10 min	**DEVELOP AN INITIAL MODEL TO EXPLAIN THE CURRENT PHASE OF THE MOON** Create an initial model of why we see the current phase of the Moon.	E-H	*Lesson 6: My Initial Model to Explain:* _____, tape
4	20 min	**PHYSICALLY MODEL LUNAR PHASES** Model the Earth-Sun-Moon system using physical objects to show how a person would see the current phase of the Moon and predict the next one.	H	Physically Modeling the Earth-Sun-Moon System
5	3 min	**NAVIGATION AND ASSIGN HOME LEARNING** Students share the word for Moon in languages that they and their families know.	J	Sticky notes or a digital survey created to collect words for Moon in other languages
				End of day 1
6	10 min	**NAVIGATION AND SHARE HOME LEARNING** Revisit the home learning in which students share words for Moon in other languages.	optional	
7	25 min	**FURTHER INVESTIGATE MOON PHASES USING AN ONLINE INTERACTIVE** Work together as a class to use an online interactive to make sense of why we see what we see when the positions of objects in the Earth-Sun-Moon system change.	K-N	*Shape Patterns of Earth-Sun-Moon System*, tape, *Lesson 6: My Initial Model to Explain:* _____ completed to predict next Moon phase, safety goggles, 4-inch Styrofoam sphere, 1 pushpin, 1 twist tie, 1 bulb socket, 1 60W light bulb, 1 extension cord with power strip, 1 plastic clamp, 12 inches of 12 gauge aluminum wire, 1 1-inch Styrofoam sphere, 5 inches of 12 gauge aluminum wire or dowel, Moon Shapes interactive (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
8	10 min	**NAVIGATION** Think more about the interaction of the Earth, Sun, and Moon, and wonder whether their interaction may affect what we see of the Moon.	O	Driving Question Board
				End of day 2

Lesson 6 • Materials List

	per student	per group	per class
Physically Modeling the Earth-Sun-Moon System materials	• safety goggles	• 1 4-inch Styrofoam sphere • 1 pushpin • 1 twist tie • 1 bulb socket • 1 60W light bulb • 1 extension cord with power strip • 1 plastic clamp • 12 inches of 12 gauge aluminum wire • 1 1-inch Styrofoam sphere • 5 inches of 12 gauge aluminum wire or dowel	
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • completed *Lesson 5 Community Guide for Looking at the Sky* • *Lesson 6: My Initial Model to Explain: _____* • tape • Sticky notes or a digital survey created to collect words for Moon in other languages • *Shape Patterns of Earth-Sun-Moon System* • *Lesson 6: My Initial Model to Explain: _____* completed to predict next Moon phase • safety goggles		• space to draw a quick sketch of the Moon • 4-inch Styrofoam sphere • 1 pushpin • 1 twist tie • 1 bulb socket • 1 60W light bulb • 1 extension cord with power strip • 1 plastic clamp • 12 inches of 12 gauge aluminum wire • 1 1-inch Styrofoam sphere • 5 inches of 12 gauge aluminum wire or dowel • Moon Shapes interactive (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Driving Question Board

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Note: Students will need two copies of *Lesson 6: My Initial Model to Explain:* _____ for their initial model of the current phase of the Moon and their prediction of the next phase.

Make sure to provide access to images of the current Moon shape for students who might not have been able to see the Moon with their own eyes due to weather conditions or safety concerns. Consider using NASA's Scientific Visualization Studio as an example, where you can view the Moon's current phase. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) They can use these images or actual observations of the Moon to complete *Lesson 5 Community Guide for Looking at the Sky* and bring that to class for this lesson.

Familiarize yourself with the Lunar Phase online interactive which students will use in step 7. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Important Parts and Interactions to Include in the Model
- The Phases of the Moon

Be sure you have materials ready to add the following phrase to the Word Wall: *phases*. Do not post this phrase on the Wall until after your class has developed a shared understanding of its meaning. You may also choose to add the names of the phases (e.g., crescent, gibbous, quarter, full).

If your students sent you home learning responses digitally, add them to the lesson slide deck after **slide A** or plan another way to share them with the class for step 1.

If you prefer to collect words for Moon in languages other than English for step 5 digitally instead of on sticky notes, create a digital survey.

Day 1: Physically Modeling the Earth-Sun-Moon System

Group size: Ideally the lab is completed in groups of 3–4 students.

- **Setup:**
  - Turn off any classroom lights. If your classroom is super bright from any windows, make sure you take the time to put up black paper or otherwise block the light from the windows so that the room is dark enough and you can easily see shadows on the Moon sphere.
  - Locate the physical models student groups created in Lesson 3.
  - Gather additional materials for each student group to use in this lesson: 1 1-inch Styrofoam sphere, 5 inches of 12 gauge aluminum wire or dowel to put Styrofoam sphere on.
- **Safety**:
  - These wire or bent paper clips are pointed at the end, so advise students to use caution.
  - Safety glasses/goggles with side shields (or indirectly vented chemical splash goggles) during the setup, hands-on, and takedown segments of the activity.

- Use only GFI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
- Use caution when working with light bulbs, which can cause skin burns or electric shock .
- Use caution when using sharp tools/materials/wires, pins, etc., which can cut or puncture skin.
- Immediately pick up any items on the floor in the work zone so they do not become a slip/fall hazard; extension cords, etc.
- Use caution when working with glassware (e.g. bulbs) which can shatter if dropped and cut skin.
- Be sure to clear the work zone of all trip/fall and slip fall hazards for students working in the dark.
- Use caution when working with dowels - they are impalement hazards and can puncture eyes and skin!
- Designate a safe place for equipment/materials upon completing the lab activity.
- Wash your hands with soap and water immediately after completing this activity.

- **Disposal**: All materials can be stored for future use.
- **Storage**: No materials are perishable—all can be stored as is convenient in your classroom.

Lesson 6 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will use physical modeling and an online interactive to observe the motion of the Moon in relation to the Sun and Earth. Students will build the ideas needed to predict lunar phases and describe why they occur. First they will look at the current phase of the Moon, then they will create a physical model, and finally, they will view a simulation of the parts of the system interacting to explore the repeating pattern of these phases over time.

Where We Are NOT Going

Students do not need to memorize the vocabulary for naming the phases of the Moon, but they should recognize how the position of the Moon and how it is illuminated by the Sun affects the shape of the Moon we see on Earth.

Students will investigate eclipses in Lesson 7, so those patterns do not need to be explained in this lesson. You will use students' questions about eclipses to navigate into Lesson 8.

At this point in their figuring out, students do not need to reason with the relative size and scale of the Moon to Earth or the relative distance of the Sun, Moon, and Earth to each other. Students will build this understanding in Lesson Set 4; when students are sensemaking about gravity, they will investigate the size and scale of the Moon and Earth using an interactive.

The orientation of the face of the Moon that we see due to tidal locking is beyond the scope of this lesson.

The Moon's rotation on its axis is beyond the scope of this unit. While students do explore the movement of the Moon around the Earth and the direction of the moonrise and moonset, they do so only from the perspective of an observer in the Northern Hemisphere.

LEARNING PLAN FOR LESSON 6

1. Navigation and Share Home Learning

8 MIN

Materials: science notebook, completed *Lesson 5 Community Guide for Looking at the Sky*, space to draw a quick sketch of the Moon

Share home learning observations of the Moon. Present **slide A**. As students come into class, collect their photos, stories, and/or drawings related to their observations of the Moon from *Lesson 5 Community Guide for Looking at the Sky* and display them around the room. If students sent you their images digitally, make a slide to go after **slide A** or share them as you planned before class.*

Give students a moment to briefly look around the room or advance through the slides to show the collected images.

Ask, *What did you notice when you looked up at the Moon or saw the image of the current Moon? What did it look like? When did you make these observations?*

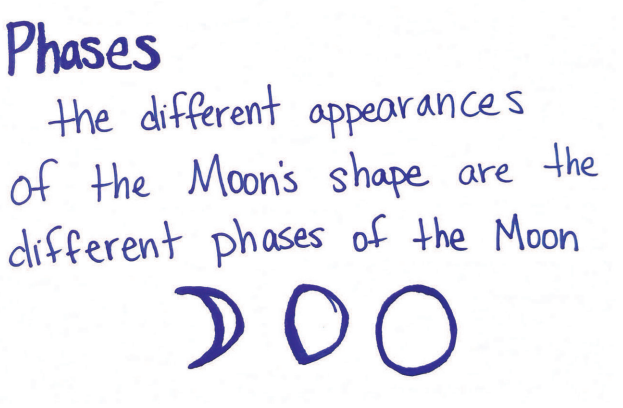
Come to consensus around what the current Moon looks like and draw an image or images reflecting the class's consensus.

Make predictions about the shape of the Moon. Present **slide B**. Say, *Does the Moon always look like the Moon you observed?* Have students turn and talk briefly about this question. Then elicit student ideas.

Sample student responses:

- No, it changes.
- Sometimes it is smaller or larger.
- Sometimes the Moon is visible during the day.
- Sometimes it is gone.
- Sometimes it's a crescent that is never bigger than half of the Moon. Sometimes it looks pregnant or lemon-shaped, rather than bitten into.
- It grows or shrinks a little each day or night.

Add "phases" to the Word Wall. Say, *These different appearances of the Moon's shape are called the different phases of the Moon*. Add "phases" to the Word Wall; see the example definition and sketches shown here.



***Attending to Equity**

If students did not all have access to a camera or drawing materials or the internet options suggested in Lesson 5, consider collecting the images anonymously and adding them to a slideshow. After viewing the images, ask for multiple volunteers to talk about an image so as not to draw attention to those students who did not bring one.

You may also choose to share an online image of the current Moon, such as is found here: (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additional Guidance

It is not necessary for you to introduce names for the specific phases of the Moon. However, students might begin using words such as "Full," "Crescent, "Waxing," "Waning," "First quarter," or "Gibbous." Press these students to describe the shape they mean when they say these words. You might ask them to come up and sketch the shape they mean,

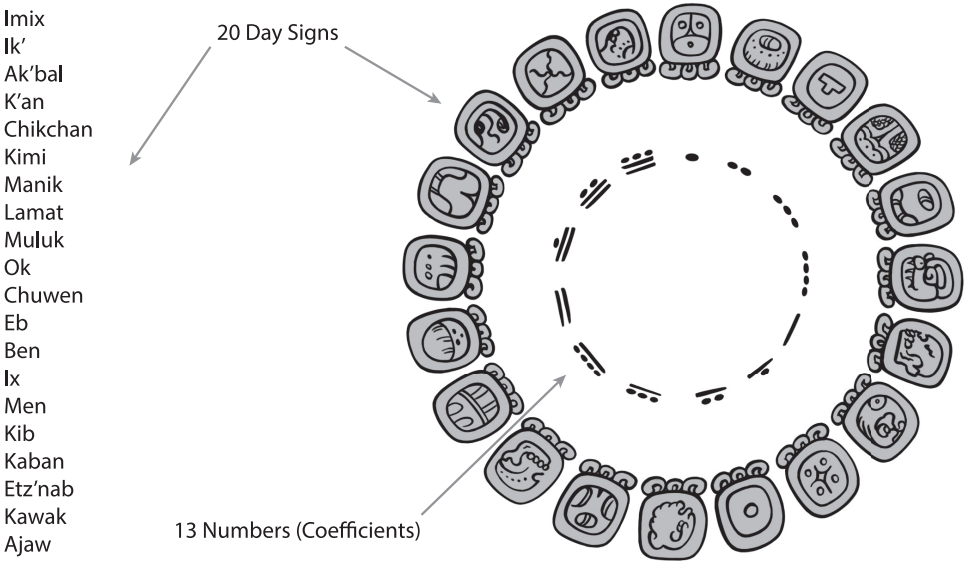
and then label it. If other students are using everyday language such as "Fingernail-shaped" (for crescent), "Half Moon" (for quarter), "Fat Moon" (for Gibbous), etc., add these words to the sketches also. It is not important that students learn this technical vocabulary but rather that the class is in agreement that these various shapes are visible so that they can communicate about them and eventually come to consensus about the causes of these changes.

2. Connect to humans across culture and time.

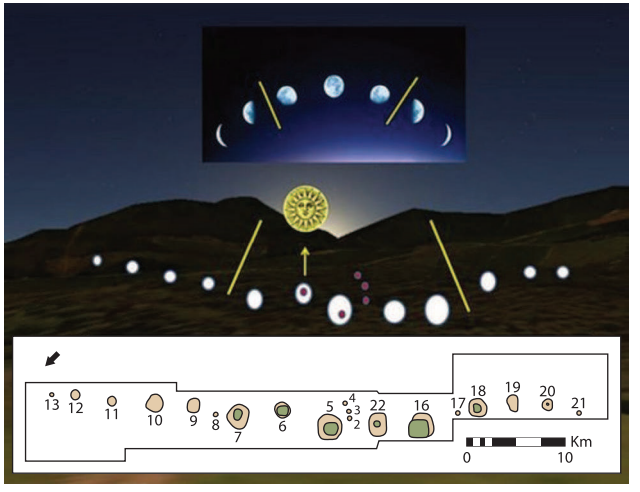
5 MIN

Materials: None

Make connections between what we see in the sky and what humans before us have documented. Display **slide C**. Say, *We're not the only ones to have noticed that the Moon appears to change shape. We know people have been using their observations of the Moon across cultures and time. We heard Professor Medupe discuss in the podcasts how the Tswana people created a calendar based on the Moon, and Professor Aldana mentioned the Mayan farmers who wait for the first full Moon after the rains start to begin their planting. This slide shows other images of some ancient representations of the Moon. While I explain the origin of each image, think about connections you can make to these representations of the Moon and why so many people have been observing and recording Moon phases.*



Mayan Moon Calendar (Mexico), 1,200 CE—The Maya sacred calendar is called *Tzolk'in* in Yucatec Mayan and *Chol Q'ij* in K'iche' Mayan. This calendar is not divided into months. Instead, it is made from a succession of 20-day glyphs in combination with the numbers 1 to 13, which produces 260 unique days (multiplying 20 × 13 equals 260). This image illustrates how the numbers 1 to 13 cycle through the 20 glyphs to form dates in the Tzolk'in calendar. Any such combination, such as 1 Imix', repeats only after 260 days have passed. The length of the Tzolk'in matches nine cycles of the Moon and the period of time between when a woman finds out she is pregnant and the birth of the child.



Calendar (Scotland), 8,000 BCE This diagram shows the arrangement of pits in a field excavated in Scotland. These pits appear to show the phases of the Moon and were likely used to keep track of lunar months.

Show **slide D**. Briefly discuss these representations of the Moon's phases. Ask, *What connections can you make with the images?*

Student responses will vary, but may include

- connections to the podcasts and/or students' own cultures,
- ideas about calendars,
- how these images compare to the sketches they made in class, etc.

Ask, *Why do you think so many people across the world observed and recorded the phases of the Moon?*

Sample student responses:

- *They're trying to figure it out; noticing the pattern repeating.*
- *They can predict what changes/shapes will happen again and in what order.*
- *They're keeping track of time so they can schedule and plan events or record the times things happen(ed).*

Summarize by saying, *People have been making observations of the Moon across time and cultures. They have also worked to understand the changing appearance of the Moon and to predict the changes. Let's go back to the way the Moon currently looks to try to figure out why we're seeing it the way we are.*

3. Develop an initial model to explain the current phase of the Moon.

10 MIN

Materials: science notebook, *Lesson 6: My Initial Model to Explain: _____*, tape

Individually develop an initial model to explain the current phase of the Moon. Distribute a copy of *Lesson 6: My Initial Model to Explain: _____* to each student. Display **slide E.** Say, *Use this handout and the directions on the slide to develop a model to show what interactions are happening with the objects in the system to cause the current phase of the Moon. Before you create your models, let's brainstorm what to include in them.*

Display **slide F**. Say, *What will we need to include in our drawings to model the current appearance or phase of the Moon?*

As students make suggestions, follow up by asking why their suggested objects and interactions are important to include. Keep a public record at the front of the classroom on a sheet of chart paper labeled "Important Parts and Interactions to Include in the Model." Given that students have created similar models previously, they are likely to include the components and interactions they've used before (e.g., Sun, Earth, person on the Earth, sunlight hitting half of the Earth) along with the Moon. Keep this model posted because you will want to refer to it again in Lesson 7.

Give students 5 minutes to complete *Lesson 6: My Initial Model to Explain: _____*. Have students tape their model into their notebooks. Say something like, *Now that we've had a chance to organize our thoughts about why the Moon looks like it does right now, we're ready to do some more investigating. We'll come back to these models in a little while to help us make sense of what we're figuring out about Moon phases*.

Additional Guidance

If students feel inhibited by the handout structure or need additional space, you can have them record their ideas on a blank piece of paper or directly into their notebooks instead of on the handout.

Decide where to go next. Display **slide G**. Ask, *What could we do to help us understand why the Moon looked like it did when we made our observations?*

Sample student responses:

- Create a physical model, like we did of Earth and the Sun to explain seasons
- Work with a simulation
- Look at photographs of the Earth-Sun-Moon system from afar
- Do research (i.e., talking to a scientist, Googling it)

Say, *Let's see if we can figure this out by modeling the system using a physical model. What will we need to include in our physical model to make sense of the current appearance or phase of the Moon?* Students should recognize that they will need the same things they included in their drawn models.

Additional Guidance

Look for students to explain something about sunlight being an important part of the system. If a student disagrees, ask them for justification. If students do not feel it is important to include the Sun or don't bring up sunlight as important to the phenomenon, you can tell them that the Moon reflects light from the Sun (we can't see the Moon without the Sun!) and that you think we should include the Sun (like we did in Lesson 2) in order to move forward.

If a student suggests including movement such as the orbiting of the Earth around the Sun, ask them for a justification for why this will help model why we see the Moon the way that we do currently (highlight that we are not looking at changes of the Moon yet, just the current phase of the Moon). If they or other students are unsure, put a question mark on the list to indicate that we are unsure if that movement is necessary.

4. Physically model lunar phases.

20 MIN

Materials: Physically Modeling the Earth-Sun-Moon System, science notebook

Work in small groups to create an initial physical model of the current lunar phase. Display **slide I.** Turn off the classroom lights and block the windows (if it is bright outside). Organize students into groups of 3–4 and provide each group with a their physical models from Lesson 3 (or 1 4-inch Styrofoam sphere, 1 pushpin, 1 twist tie, 1 bulb socket, 1 60W light bulb, 1 extension cord with power strip, 1 plastic clamp, 12 inches of 12 gauge aluminum wire) and the new materials for this lesson: 1 1-inch Styrofoam sphere, 5 inches of 12 gauge aluminum wire or dowel, and safety goggles.*

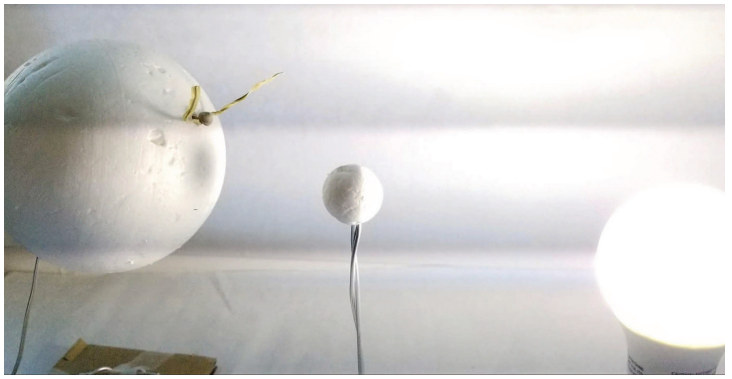
Remind students that the round pushpin represents someone looking up from their location on Earth.

Ask, *How can you get the little person (twist tie and round pushpin) to "see" something that looks like the current phase of the Moon?*

Give students about 10 minutes to play around in small groups. As they work, move from group to group and listen to students' conversations. Students may do the following:

- **Struggle to change perspective.** These students might say something like, "Everywhere we move the Moon, I always see half dark and half light." If you hear a student struggling to change perspective, say, *You say that you always see the same thing. But would you see the same thing if you were a tiny person standing on top of that pushpin? What would that person see?*
- **Struggle to connect light to the parts of the Moon that we see.** These students might say something like, "I think the person can see the Moon from everywhere, I don't get it." If you hear a student struggling to connect light to the appearance of the Moon from Earth, ask, *What do you notice about how the sunlight interacts with the Moon? Would the observer see the lit half, dark half, or something else?*

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
At this point in their figuring out, students do not need a scientifically accurate scale model of the Earth-Sun-Moon system. This lesson is about positioning those objects related to how the position affects the pattern or shape of the Moon we see. It is OK to foreground for students that considering scale is a great line of questioning that reminds us to figure out more about the size and scale of distance of these objects (and others) in our solar system. It also reminds us how important perspective is when we are modeling objects in the sky and space.



Additional Guidance

When referring to the dark or unlit side of the Moon, the term *shadow* is not used. If students use the term *shadow*, ask students to recall what a shadow is. When an opaque object blocks light, it creates a shadow. This is different from light not reaching an object. For example, if a person is in an unlit room, we would not say they are in a shadow, just that there is no light. The dark side of the Moon is the same. When students explore solar eclipses in the next lesson, they will consider the shadow that the Moon casts onto the Earth and the distinction between unlit and shadowed may be helpful for sensemaking.

Revise initial models. Students should reach consensus on how to show the current phase of the Moon in their 3D models. Then students should stay in their small groups and modify their individual models on the copy of *Lesson 6: My Initial Model to Explain:* _____ in their notebooks from earlier today. If students need additional space, you can have them record their updated model elsewhere in their notebooks instead of on the handout.

Use models to predict the next phase of the Moon. Display **Slide I.** Say, *We noted that the appearance of the Moon changes. Use the models you have developed to make a prediction about what the Moon will look like next. What will the next phase be*?



Give students a new copy of *Lesson 6: My Initial Model to Explain:* _____. Allow students to work in small groups with their physical models to make a prediction and then record it on the handout. Don't have students put this handout in their notebooks yet; instead, collect them at the end of the period to inform your work next time. If students ask about whether the Moon should be getting bigger or smaller, reassure them that it is OK if they do not know and that you are more interested in their reasoning.

Assessment Opportunity

Building towards: 6.A Develop and use a model of the Earth-Sun-Moon system to explain and predict patterns we observe in the way the apparent shape of the Moon changes over time.

What to look look for:

- In the first section of this copy of *Lesson 6: My Initial Model to Explain: _____*, students should sketch the Moon appearing slightly larger or smaller than it is currently. We haven't yet figured out the direction of the orbit, so they likely won't know if it's waxing or waning. If the current phase is a quarter Moon, students may draw a gibbous or crescent Moon. Do not expect students' sketches to be exact, and expect that they may show more than a day's change. For example, if the current phase is a full Moon, there will likely be variety in the size of students' drawings of a gibbous Moon.
- In the second section, students' models should show the Moon a bit farther along in its orbit (again, we haven't yet figured out the direction) than it was to model the current phase and show its position relative to the Earth and Sun that results in an observer seeing that next phase.

What to do:

- If students are struggling with taking the perspective of the person on Earth, the interactive on Day 2 may help them switch perspectives. Consider having them recreate their physical models after viewing the interactive to see if they are now able to demonstrate and explain why the Moon will look the way it does using the physical model.

5. Navigation and assign home learning. 3 MIN

Materials: Sticky notes or a digital survey created to collect words for Moon in other languages

Navigation to next time's work. Say, *We will continue to explore Moon phases and reflect on our predictions next time we meet.*

Present a home learning opportunity. Present **slide J**. Ask students to share the word for Moon in another language they are familiar with. Students can research the word for Moon in another language by speaking to their friends and family or by looking it up. Multilingual students may be ready to share right away. You may choose to have students record these words on sticky notes to add to a poster or in a shared digital document. Creating this space to share without judgement will honor in the classroom the knowledge brought by family and community, legitimize the resources emergent multilinguals bring to the classroom, and give emergent-multilingual students the opportunity to make content connections in their first language. Students may add other ideas, stories, and interpretations for these words. If students prefer or need to do research at home, words can be collected physically or digitally at the beginning of Day 2.

Alternate Activity

Extension Opportunities:

If time permits, the video (3.18 minutes) shows a diverse set of individuals—diverse in terms of age, race, and gender—reacting to seeing the Moon through a telescope. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Two people's reactions are bleeped out as they contain language inappropriate for the classroom, but it is still obvious they say something inappropriate.

Additionally, the video (6:46 minutes) tells the story of how the famous Earthrise image was captured. It has images of the Moon as well as looking at Earth from a different perspective. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) The Earth is half lit, which relates to what students are making sense of with the Moon in this lesson.

End of day 1

6. Navigation and Sharing Home Learning

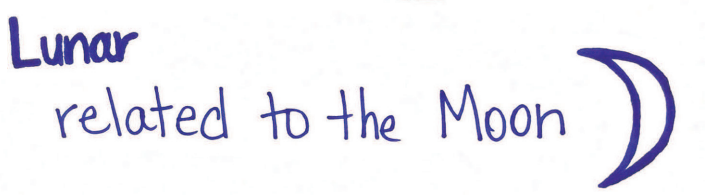
10 MIN

Materials: None

Collect words for Moon. If you didn't already collect words for Moon from students before class, do so as they come in and display them in the room (e.g., on a poster or the optional slide). Depending on the words brought in, you may choose to share some or all of the following information with the class.

The word *Moon* probably comes from the Old English word *mona*, which stems from *menon* or *mensis* (for month). The root of the word is found in many languages, including Old Germanic, Old Saxon, Old Dutch, and Old Nordic, which have similar words. In Spanish (*luna*) and French (*lune*), the words most commonly used for Moon come from the Latin word for Moon, *luna*, which is the name of the Roman goddess of the Moon, which is taken from the Greek word selas, which means brightness (Science Diction: The Origin of the Word "Moon". 2012, January 20).

Note that in this teacher guide we use both phrases: *the phases of the Moon* and *lunar phases (*from the root word *luna).* "Lunar" might connect to cognates in other languages and help students make connections to *lunar eclipses* in Lesson 8. You may choose to only use "Moon phases" or also use "lunar phases" depending on which is more familiar to your students. If you choose to use "lunar," make sure to add it to the Word Wall.



7. Further investigate moon phases using an online interactive.

25 MIN

Materials: *Shape Patterns of Earth-Sun-Moon System*, science notebook, tape, *Lesson 6: My Initial Model to Explain:* _____ completed to predict next Moon phase, safety goggles, 4-inch Styrofoam sphere, 1 pushpin, 1 twist tie, 1 bulb socket, 1 60W light bulb, 1 extension cord with power strip, 1 plastic clamp, 12 inches of 12 gauge aluminum wire, 1 1-inch Styrofoam sphere, 5 inches of 12 gauge aluminum wire or dowel, Moon Shape interactive (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Share predictions about the next phase of the Moon. Display **slide K.** As the class moves into a Scientists Circle, redistribute the copies of *Lesson 6: My Initial Model to Explain:* _____ where students predicted the next Moon phase, which you collected last time.

*** Supporting Students in Engaging in Developing and Using Models**

Consider asking students whether they notice any limitations of the model used in this interactive. Because students have previously

Ask students to share their predictions about the next phase of the Moon with an elbow partner. Then elicit ideas from the class. Have a physical model ready in case students would like to use it to demonstrate their thinking.

Ask, *How can we check our predictions?* Listen for students to suggest that we use a simulation to confirm our predictions. If students suggest making direct observations, point out that is a good option and ask if there is a way to check right now in class. You could even ask, *What would be the benefits of using a simulation?*

Display **Slide L**. Say, *I have an interactive online that simulates the phases of the Moon. A simulation is also a model. Just like we used our observations and understanding of the Earth, Sun, and Moon to create models to explain how we could see the Moon, people have used their observations and understanding to create this dynamic computer model to simulate the positions of the objects in this system. We can interact with it—move the objects around—to see how they interact. Let's take a look and see if it matches our predictions.**

Project the Moon Shape interactive. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Orient the class to the interactive. Explicitly discuss with students how the perspective of this interactive (looking down on the North Pole of Earth from above in space), is different from the way we have previously represented the Earth-Sun system (hovering next to the system, over the equator of Earth).

Do not yet turn on the extra features (time tick marks, lunar landmark, or moonrise/moonset line).

Make sense of Moon phases using the interactive. Click the play button and let the interactive run while you watch at least two phase changes. You may choose to let it keep running or pause it as you discuss the following questions.

Suggested prompts	Sample student responses
What does the dark side of the Earth represent? *If helpful, point out that the interactive includes "Time Tick Marks" to help us make sense of what the person on Earth is experiencing.*	*night time*
When looking down at the North Pole like in this interactive model, how would we describe the way the Moon moves around the Earth?	*It is going around counterclockwise.*
What can you say about how the sunlight interacts with the Moon?	*The Moon is always half-lit.*
Does this match what we saw in our physical model?	*Yes. (If students aren't sure, use the physical model again as a class.)*
Does the Moon always look half-lit to us here on Earth?	*no*
How can the Moon appear different to us when it is always half-lit?	*We are seeing different parts of the lit half of the Moon based on the locations of the Moon.*

discussed the variation in the amount of daylight over the year due to location and the tilt of the Earth, they may notice that this model does not account for the tilt of the Earth or its orientation in relation to the Sun. These aspects of the Earth-Sun system are not necessary to figure out the phases of the Moon, so it is not necessary to represent them in this model. Model limitations will be further addressed in Lesson 7.

*** Supporting Students in Developing and Using Patterns**
Students should demonstrate that they understand that the cycle of lunar phases is going to repeat and that it will do so because the Moon will continue to move around the Earth. This phase-change cycle takes about 29 days.

Compare what we see on the interactive to our physical models. Encourage students to use the physical model to explain that we're seeing different views of the half-lit Moon. Continue with the following specific examples to aid students' sensemaking.

Suggested prompts	Sample student responses
Navigate the interactive to a crescent Moon with the person "underneath" the Moon and ask, *Why would the person see the Moon this way, as a crescent or fingernail-shaped?*	*They are only seeing a small part of the lit half of the Moon.*
Navigate to a quarter Moon with the person "underneath" the Moon and ask, *Why would the person see it this way?*	*They can only see half of the lit half of the Moon.*
Navigate to a gibbous Moon with the person "underneath" the Moon and ask, *Why would the person see it this way?*	*They can see most of the lit half of the Moon.*
Navigate to a full Moon with the person "underneath" the Moon and ask, *Why would the person see it this way?*	*They can see all of the lit half of the Moon.*
Ask, what phase (what shape) would come next? Why? Then what? *Keep asking, "Then what?" until students make it back to the new Moon and recognize that the pattern will start over.*	*Students should be able to answer each following lunar phase and justify their prediction based on their understanding of the Moon's counterclockwise movement and location relative to the Sun and observer.*

Use the interactive to check the lunar cycle timeframe. If students did not notice the length of the lunar cycle when the simulation ran, say, *Let's see if we can check with the model*. Let the simulation run from a new Moon to a new Moon while keeping an eye on the "Time since new Moon." Discuss using prompts such as these:*

Suggested prompts	Sample student responses
How long does this whole cycle take? why?	*29 days, a month, 28–30 days, something close to a month.* *This is how long it takes the Moon to orbit the Earth.*
How can we know how long this cycle takes?	*We can observe how long it takes for the phases to start over (in this interactive and/or in real life!).*

Use the interactive to consider how we see moonrise and moonset in our sky. Turn on the moonset/moonrise marker. Navigate to a waxing crescent with the person just past the moonrise line. Ask, *What direction would the person need to look to see the Moon?* (Elicit *East.*)

Ask, *So what does that mean in terms of where the Moon appears to rise and set?*

Elicit, *It would appear to rise in the East and set in the West.*

If it's helpful, you can move the person to the moonset line and consider which direction they would need to look to see the Moon.

Alternate Activity

If students are curious about the orientation of the Moon or the "lunar landmark" feature, you can turn on the "lunar landmark" and explore it. After watching the simulation with this feature on, ask, *What did this landmark allow us to see about the Moon?* (*The same side of the Moon is always facing Earth, so we're always seeing the same side.*)

You may also want to use NASA's Scientific Visualization Studio to observe how the side of the Moon facing Earth stays the same over time. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

If students wonder why this is the case, add a question to the DQB and make sure they have a chance to read the supplemental reading after Lesson 14.

Record positions of the Moon for each phase. Say, *I have a reference for us to add to our notebooks. Why will it be helpful to keep sketches and notes about how the Moon's position causes us to see different phases?*

Sample student answers:

- *This is the first time we've added the Moon to our Earth-Sun system, and we want to record how that object interacts with the others (not just for the current phase, since it changes!).*
- *Writing/drawing things myself helps me remember them.*
- *We still have other Moon-related questions, so maybe we can build on these models to answer more of those.*

Display **slide M** and hand out a copy of *Shape Patterns of Earth-Sun-Moon System*. Direct students to add it to their science notebooks.

Take a minute to orient students to the differences between *Shape Patterns of Earth-Sun-Moon System* and the Moon Shape interactive such as the people figures placed at different times of day and the arrows to represent the spin of Earth.

Give students about 10 minutes to complete the chart and models and tape it in their notebooks.

If students need help figuring out how and what to add to their model, refer the class back to the Moon Shape interactive and ask them to tell you how to change it to make the shape of the Moon appear. Then, have them add what they see with the Moon, and the sunlit and non-sunlit portions of the Moon.

Alternate Activity

If students have access to their own devices, individually or with a partner, you could send them back to their desks and have them interact with the Moon Shape interactive themselves to support their work on *Shape Patterns of Earth-Sun-Moon System*.

Additional Guidance

Do not expect students to be exact about waxing or waning phases. Accept a crescent Moon that is at the top left of the orbit or at the bottom left of the orbit.

Assessment Opportunity

Building towards: Develop and use a model of the Earth-Sun-Moon system to explain and predict patterns we observe in the way the apparent shape of the Moon changes over time.

What to look/listen for: Check to make sure students are including these details:

- Describing each lunar phase.
- Adding the Moon on the circle that represents its orbit in the position related to each phase.
  - Do not expect students to be exact about waxing or waning phases.
  - Accept crescent and gibbous Moons at the top left/right of the orbit or at the bottom left/right of the orbit.
- Distinguishing the lit and unlit sides of the Moon.

What to do:

- If students are not accurately distinguishing the lit and unlit sides of the Moon, encourage them to return to the physical model and make observations of the sunlight on the Moon.
- If the placement of the Moon is inaccurate, have students draw lines from the observer to the sides of the Moon facing Earth to more concretely frame how much of the lit part of the Moon the observer could see.

Create a class version of the Moon phases chart. Display **slide N.** Bring the class back together and ask students to volunteer to share their understanding of each phase. As students share, record at the front of the room a version of the diagram from *Shape Patterns of Earth-Sun-Moon System* on a sheet of chart paper labeled "The Phases of the Moon." Again, point out the perspective of looking down on the North Pole of Earth. Add the position of the Moon in the system for each phase as students share. Add two Moons for the crescent and gibbous Moons.

Ask students how to show the unlit side of the Moon in *Shape Patterns of Earth-Sun-Moon System* and decide how you will represent this as a class. The convention used throughout this unit is a striped region, but each class may choose something different. Keep track of the choice in a key on the diagram you are making, and reassure students that it is OK if they used a different representation for the unlit side of the Moon; the important thing is that they represented it in some way.

Additional Guidance

If students refer to the "dark side" of the Moon, push them to explain what they mean. They likely are thinking of the side of the Moon we don't see from Earth, but that doesn't mean it's always dark there. Have the student(s) work with the physical model and/or interactive to show that all "sides" of the Moon are in fact lit by the Sun at some point. To be clear, we talk about how much of the lit and unlit halves of the Moon we can see at any given time, rather than calling one side "dark."

Label each phase on the poster with the technical names seen in the interactive such as *new Moon, crescent Moon, quarter Moon, gibbous Moon, full Moon* or with names the class agreed-on earlier in the lesson (e.g., fingernail-shaped). The purpose is to have a common language in case the class wants to refer to a specific phase.

If you are introducing new vocabulary (like gibbous), be sure to point this out explicitly. Add any new terms to the Word Wall and give students a chance to record them on *Shape Patterns of Earth-Sun-Moon System*.

8. Navigation

10 MIN

Materials: Driving Question Board

Continue using the interactive to explore how we see the Moon at different times. Display **slide O.** Set the interactive such that there is a new Moon and the person is as close to the Sun as possible. Use prompts such as the following to establish that sometimes we can see the Moon during the day.

Suggested prompt	Sample student responses
What is the person experiencing in this location (as close to the Sun as possible)?	*This is the daytime.* *It is around noon.*

Navigate to a small crescent Moon (no more than 20% illumination) with the person "underneath" the Moon.

Suggested prompts	Sample student responses
So what time of day is it—approximately—for this person?	*Afternoon (or morning, depending on whether you are showing a waxing or waning crescent Moon).*
Can a person see the Moon at that time of day?	*Maybe?* *Probably?* *Yes, if the Sun isn't too bright?*

Keep the Moon at this small crescent, but move the person's figure to midnight. Ask, *Would the person see the Moon at this time?* Sample student response might include:

- No, because the Moon would not be in their line of sight.

At this point, turn on the "Moonrise/Moonset Line" feature of the interactive and explore what times of day people can see the Moon. The goal is just to recognize that we can sometimes see the Moon during the day.

Navigate toward exploring eclipses. Adjust the interactive to show a new Moon (0% illumination) with the person "underneath" the Moon.

Say, *So we've been figuring out what we can see of the Moon over time, and now that we know the Moon can be out during the day, I'm wondering: can the Moon affect what we see of the Sun (like in the case currently shown in the interactive)? What do you think?* Sample student responses:

- *I'm not sure.*
- *Maybe...*
- *Does the Moon get in the way of the Sun?*
- *That would cause an eclipse.*

If someone mentions an eclipse, say, Tell us more ... what do you mean by that? If there are questions about eclipses on the DQB, refer to those now, saying something like, *Eclipses involve the Earth-Sun-Moon system, too.* In either case, say, *Let's investigate this more next time.*

ADDITIONAL LESSON 6 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.

Students explore the word Moon in several languages and discuss the cognates of "lunar." The class settles on agreed-upon terms to specifically name the phases of the Moon.

LESSON 7

Why do we see eclipses and when do we see them?

Previous Lesson

We used a physical model to help make sense of the positions of the objects in the Earth-Sun-Moon system that caused us to see the current shape of the Moon and to predict the next phase of the Moon. We used an interactive to help us explain how changes in the position of the Moon affect what we see.

This Lesson

Investigation

2 DAYS





NASA/Gopalswamy

We watch a video of a solar eclipse. We develop a model to explain what we saw in the video using a physical model of the system. We compile the ideas we want to include in a drawn model using multiple perspectives to communicate what is seen when a solar eclipse happens and why. We return to our physical models to figure out why we do not see a solar eclipse every month and how often we might expect to see a solar eclipse.

Next Lesson

We will analyze images of lunar eclipses and compare them to the predictive model we made as a class. The reddish color of the Moon we will observe during a lunar eclipse will surprise us. We will list possible causes of that reddish color, gather examples of related phenomena, and generate ideas for investigating our color-related questions.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2



What Students Will Do

7.A Develop and use a model of the Earth-Sun-Moon system to explain why and when we can see a solar eclipse.

What Students Will Figure Out

- Sometimes the Moon lines up in its orbit between the Sun and the Earth, resulting in the Moon casting a shadow on the Earth. This is what causes a solar eclipse.
- The Moon's orbit is not perfectly flat relative to Earth's orbit around the Sun; it is tilted just a little. This is why we don't see eclipses every month.

Lesson 7 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Revisit our questions about eclipses (from last class and from the Driving Question Board).	A	DQB
2	10 min	**OBSERVE A SOLAR ECLIPSE** Watch a video of a solar eclipse. Record noticings and wonderings in science notebooks, then share them with the class.	B-C	8.4 Lesson 7 Total Solar Eclipse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
3	10 min	**DEVELOP AN INITIAL MODEL TO EXPLAIN THE SOLAR ECLIPSE** Students create an initial model of why we see a solar eclipse.	D-G	*Lesson 7: My Initial Model to Explain: _____*, tape, "Important Parts and Interactions to Include in the Model" chart, 1-inch foam sphere, 38 inches of 12-gauge aluminum wire
4	15 min	**MODEL SOLAR ECLIPSES** Model the Earth-Sun-Moon system using physical objects to figure out what interactions are occuring during solar eclipses.	H-I	*Lesson 7: My Initial Model to Explain: _____*, Physically Modeling a Solar Eclipse
5	5 min	**NAVIGATION** Consider whether there is an eclipse with every New Moon.		
				End of day 1
6	15 min	**NAVIGATION AND GROUPS MODEL NEW MOON WITHOUT AN ECLIPSE** Model the Earth-Sun-Moon system using physical objects to figure out whether there can be a New Moon without an eclipse.	J-L	*Lesson 7: My Initial Model to Explain: _____*, Day 1 Solar Eclipse Model, Physically Modeling a Solar Eclipse
7	18 min	**MODEL NEW MOONS THROUGHOUT THE YEAR** Model the New Moon throughout the year using physical objects to figure out when there might be an eclipse.	M-N	"Important Parts and Interactions to Include in the Model" chart, Physically Modeling a Solar Eclipse
8	5 min	**UPDATE PROGRESS TRACKERS** Update our Progress Trackers.	O	
9	5 min	**REFLECT ON MODEL BOUNDARIES DISCUSSION** Consider the different models the class made and how their different purposes related to their boundaries.	P	*Lesson 7: Self-Assessment for Collaborative Group Work*, Class consensus model

Part	Duration	Summary	Slide	Materials
10	7 min	**NAVIGATION** Predict what we would see when there is a lunar eclipse.	Q	chart paper
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 7, students are ready to read Student Reader Collection 2 and then respond to the writing exercise.		Student Reader Collection 2: *Reaching for the Moon*

Lesson 7 • Materials List

	per student	per group	per class
Physically Modeling a Solar Eclipse materials	• safety goggles	• 1 4-inch Styrofoam sphere • 1 pushpin • 1 twist tie • 1 bulb socket • 1 60W light bulb • 1 extension cord with power strip • 1 plastic clamp • 12 inches of 12 gauge aluminum wire • 1 1-inch Styrofoam sphere (can be reused from Lesson 6) on 38 inch circle of 12-gauge aluminum wire	

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Lesson 7: My Initial Model to Explain: _____* • tape • *Lesson 7: Self-Assessment for Collaborative Group Work*		• DQB • 8.4 Lesson 7 Total Solar Eclipse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • "Important Parts and Interactions to Include in the Model" chart • 1-inch foam sphere • 38 inches of 12-gauge aluminum wire • Day 1 Solar Eclipse Model • Class consensus model • chart paper

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Total Solar Eclipse 2017 video at 8.4 Lesson 7 Total Solar Eclipse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Make sure you can hear the audio.

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- "What Will Move/What Will Not Move" T-chart
- "How does a solar eclipse happen?" consensus model
- "Why don't we see a solar eclipse with every New Moon?" consensus model
- "How often might we see a solar eclipse?" consensus model

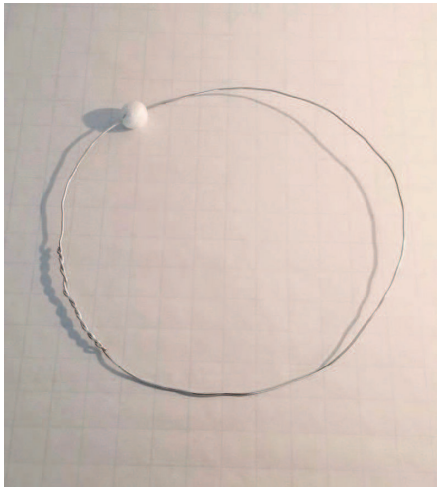
Have the chart created in Lesson 6 available: Important Parts and Interactions to Include in the Model

Be sure you have materials ready to add the following word to the Word Wall: *eclipse*. Do not post this on the Word Wall until after your class has developed a shared understanding of its meaning.

Physically Modeling a Solar Eclipse Lab

- **Group size:** approximately 4-5 students per group
- **Setup:**
  - Keep the physical modeling materials from Lessons 6 available.
  - Between Day 1 and 2, put the smaller (1-inch) Styrofoam ball representing the Moon on a piece of wire (about 38 inches long) by punching a hole in the Styrofoam ball with the wire and stringing it like a bead. Then make a circle out of the wire to represent the orbit of the Moon around the Earth.

- **Safety**:
  - Sticks, wire or bent paper clips are pointed at the end, so advise students to use caution.
  - Safety glasses/goggles with side shields (or indirectly vented chemical splash goggles) during the setup, hands-on, and takedown segments of the activity.
  - Use only GFI protected circuits when using electrical equipment, and keep away from water sources to prevent shock.
  - Use caution when working with light bulbs, which can cause skin burns or electric shock
  - Use caution when using sharp tools/materials/wires, pins, etc., which can cut or puncture skin.
  - Immediately pick up any items on the floor in the work zone so they do not become a slip/fall hazard; extension cords, etc.
  - Use caution when working with glassware (e.g. bulbs) which can shatter if dropped and cut skin.
  - Be sure to clear the work zone of all trip/fall and slip fall hazards for students working in the dark.
  - Use caution when working with dowels - they are impalement hazards and can puncture eyes and skin!
  - Designate a safe place for equipment/materials upon completing the lab activity.
  - Wash your hands with soap and water immediately after completing this activity.
- **Disposal**: All materials can be stored for future use.
- **Storage**: No materials are perishable—all can be stored as is convenient in your classroom



Lesson 7 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will make sense of a total solar eclipse. However, the lesson often simply uses the term "eclipse" since the total solar eclipse is the only one students are focused on at this point. Students develop multiple models in small groups and as a whole class—switching perspectives as necessary—to make sense of how an eclipse occurs and what an observer would see.

Part of understanding what an observer would see and why includes exploring the pattern of when eclipses occur. For example, what is the pattern of solar eclipses? Students begin to investigate the patterns and causes of those patterns on Day 2 of the lesson. If the class is short on time and there are no students about the frequency of eclipses, this can be skipped.

Where We Are NOT Going

Students will figure out that the Moon's orbit around Earth is tilted relative to Earth's orbit around the Sun; they do not need to know, model, or calculate the exact degree of this tilt.

Students will not make sense of partial solar or annular eclipses nor will they need to know the parts of a shadow (e.g., umbra).

A1lthough the occultations of stars by the Moon connect back to the podcasts in Lesson 1, do not hold students accountable for the word *occultation* or add it to the Word Wall in this lesson.

While students will discuss orbits in this lesson, they will not address gravity's role in the orbits unit Lessons 14 and 15.

LEARNING PLAN FOR LESSON 7

1. Navigation

5 MIN

Materials: DQB

Navigate to where we left off last time. Say, *We have explained why the Moon appears to change shape over the course of a month. But we also realized that we have other questions about the interaction of the Moon and Sun—we were wondering about eclipses.*

Display **slide A**. Quickly form groups of three or four students. Have them talk with their groups about the following questions:

- *Have you observed an eclipse or heard about what people can see when one occurs?*
- *What do you think is going on when there is an eclipse?*

After about 2 minutes of group talk time, have several students share an experience they heard about in their group. As questions arise during the whole group share out, capture them on the DQB.

Also, point to other DQB questions about eclipses and read some of those. (Note: if students have questions about what causes the movement of the parts of the system that result in eclipses—e.g., Why does the Moon move around the Earth?—those questions will not be addressed at this point, but gravity will be addressed later in the unit.)

Ask, *What could we look at to give us a better idea of what an eclipse is?* Listen for students to suggest viewing a video or photographs of an eclipse.

Alternate Activity

While many people view eclipses as a cause for celebration, in some indigenous communities eclipses are seen as a bad omen or it may be taboo to look at videos or images of them. According to Rudy Begay, a Navajo cultural resource specialist consulting with various federal programs, "when there is an eclipse either lunar or solar, this is a sacred time where the sun, the moon and the earth is kind of like in an intimate position when they line up, so it's such a sacred thing that's happening, you don't look at those things that are happening out in the sky" (Braine, T. 2017, August 18. *Avert Your Eyes: Eclipse Viewing Taboo in Navajo and Other Cultures*.)

Be thoughtful about the students in your classroom, and if you believe viewing eclipses may be an issue for anyone, work with the student to identify alternatives to viewing eclipses that they feel comfortable with. These might include using occultations of other celestial objects by the Moon (such as other stars or planets) in either images, videos, or interactives like Stellarium to demonstrate how objects can block other objects. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Another option is to have students look at images of the shadows created by eclipses and cast onto places on Earth instead of the eclipse itself. While students might not feel comfortable viewing an eclipse, modeling one in subsequent activities may or may not require alternatives.

2. Observe a solar eclipse.

10 MIN

Materials: science notebook, 8.4 Lesson 7 Total Solar Eclipse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Watch a video of a solar eclipse. Present **slide B**. Say, *I have a video here of a solar eclipse. Since we don't all have the same experiences or background knowledge about eclipses, we can watch this video together and see what we notice about what an eclipse is, and see what other questions we have about them.*

Have students make a Notice and Wonder chart in their notebooks to record their observations and questions. As you are starting the video, say, *This is Derek. He makes videos about different scientific phenomena and posts them on YouTube; 8.8 million people subscribe to his channel. In this video, Derek travels from Los Angeles, CA to Madras, OR to see the solar eclipse of 2017.*

The purpose of sharing this information is to highlight that Derek needed to travel to see the eclipse because they are not viewable everywhere. Additionally, pointing to the number of subscribers demonstrates that there is a large number of people who are interested in learning more about science.



NASA/Gopalswamy

Play the solar eclipse video at 8.4 Lesson 7 Total Solar Eclipse and allow students to just watch. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Then ask them to record noticings and wonderings in their science notebooks before playing the video a second time. As they are watching the video again, students can write any additional noticings and wonderings in their charts. You do not need to watch the whole video a second time, just 0:40 to 1:25, 1:58 to 2:45, and 4:16 to 4:34.

Share noticings and wonderings about solar eclipses. Present **slide C**. Ask students to share out what they noticed and wondered about the solar eclipse in 8.4 Lesson 7 Total Solar Eclipse (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Additional Guidance

If students mention lunar eclipses, say, *Good point! There are solar eclipses and lunar eclipses. Let's focus on one at a time. Since we have started thinking about solar eclipses, let's stick with that for now and then shift to lunar eclipses next.*

Summarize and move to the next step by saying something like, *We have some great initial ideas about what's going on when a solar eclipse happens. Let's draw initial models to organize our ideas and identify some questions we still have.*

3. Develop an initial model to explain the solar eclipse. 10 MIN

Materials: science notebook, *Lesson 7: My Initial Model to Explain:* _____, tape, "Important Parts and Interactions to Include in the Model" chart, 1-inch foam sphere, 38 inches of 12-gauge aluminum wire

Individually develop an initial model to explain a solar eclipse. Distribute a copy of *Lesson 7: My Initial Model to Explain:* _____ to each student. Display **slide D.** Direct students to develop a model to show what interactions are happening with the objects in the system to cause the solar eclipse.

Give students 5 minutes to complete *Lesson 7: My Initial Model to Explain:* _____. Have students tape their model into their notebooks.

Give students 2 minutes to turn and talk with a partner to identify similarities and differences between their models and what questions they have about solar eclipses.

Additional Guidance

If students feel inhibited by the handout structure or need additional space, you can have them record their ideas on a blank piece of paper instead of on the handout.

Decide where to go next. Display **slide E**. Say, *What could we do to help us understand what causes an eclipse?*

Sample student responses:

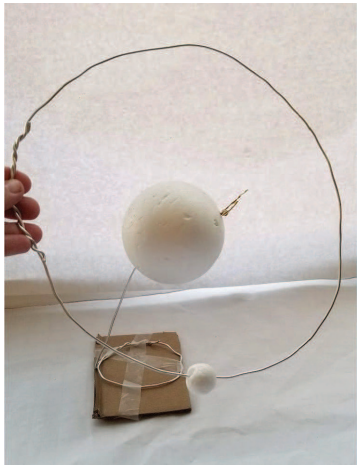
- Create a physical model (like we have done before).
- Work with a simulation.
- Look at photographs of the Earth-Sun-Moon system from afar.
- Do research (i.e., talking to a scientist, Googling it).

Say, *Let's see if we can figure this out by modeling the system using a physical model.* Display **slide F**. Say, *What will we need to include in our physical model to make sense of the cause of eclipses?*

Reference your list of the "Important Parts and Interactions to Include in the Model" from the previous lesson, and ask if anything needs to be added or removed. As students make suggestions, follow up by asking why their suggested objects and interactions are important to include. Students may suggest adding the motion of the Moon around Earth, or they might say that we already have all the components we need listed already.

Display **slide G**. Say, *I noticed the circle that represented the Moon's orbit in the models we used last time—in the interactive and on the handout where we recorded the Moon's phases—so I decided to put the Moon on an orbit.* Show the update you made to the modeling supplies. Point out to students that the relative size of the orbit is not to scale.





Additional Guidance

If a student recognizes that adding the orbit (i.e., putting the Moon on the wire) will not allow the Moon to have the lit side of the Moon remaining consistent, say, *Good point, let's think about the limitations of this model and what we are trying to figure out.* Elicit the idea that the goal of this modeling is to figure out solar eclipses. We do not need to

represent the way that the Moon faces Earth in order to do this. If this does not come up at this point, students will have a structured opportunity to think about the limitations of the model later in the lesson.

4. Model solar eclipses.

15 MIN

Materials: Physically Modeling a Solar Eclipse, science notebook, *Lesson 7: My Initial Model to Explain: _____*

Model a solar eclipse in groups. Using the provided modeling supplies, ask students to work in groups to use the physical model to demonstrate what is going on during a solar eclipse like the one we saw in the video. After some initial group work time, this will be an iterative process of students modeling in small groups, responding to teacher questions, and sharing across the room.

Before groups begin working together, check in on class norms and discuss how they are important for group work. Tell the class that they will get a chance at the end of the period to reflect on their own participation in today's group work. Student groups can continue to use their physical models from Lesson 3 in addition to the 1 1-inch Styrofoam sphere (can be reused from Lesson 6) on a 38-inch circle of 12-gauge aluminum wire.

Display **slide H** and give students 8 minutes in their groups to work together to figure out what is going on during a solar eclipse. While students work, check in with each group to assess students' understanding of how a solar eclipse happens. You might use prompts such as these to elicit students' ideas about their physical models:



- *How are the Earth, Sun, and Moon interacting to make the eclipse happen?*
- *How do you know the observer (push pin) will see a solar eclipse?*
- *Are there areas of Earth that would not see this eclipse? How do you know?*
- *How did these physical modeling materials help you describe and explain a solar eclipse?*

Assessment Opportunity

Building towards: 7.A Develop and use a model of the Earth-Sun-Moon system to explain why and when eclipses can be seen.

What to look/listen for: Students' models should identify the alignment between the Earth, Sun, and Moon to explain why solar eclipses occur. Look for an alignment of the Earth, Moon, and Sun that results in the Moon's shadow being cast on Earth causing the observer to experience an eclipse.

What to do: If students haven't figured out how to model a solar eclipse when you get to their group, ask questions such as the following to help them describe what's happening during a solar eclipse, and then see if they can use their physical materials to represent that.

- *What did the people in the video see during the solar eclipse?*
- *Where would the Moon need to be relative to this person (push pin) for them to see something similar?*

If students are struggling, ask them to identify an object blocking their ability to see another object in their immediate vicinity, such as a classmate's body blocking their view of the projector screen. Use that example to draw a parallel to the Moon blocking the Sun.

*** Attending to Equity**

Supporting Emergent Multilingual Students: Students who are learning English benefit from redundancy of content and vocabulary. One way to give students the opportunity to hear ideas again is to revoice them. For example, after students have shared what we figured out, check to clarify what students agree upon by asking, "So I'm hearing _____ and _____. Do I have that right?" For all science students, but particularly those who are learning English, the opportunity to hear scientific language in varied contexts is fundamental to the development of disciplinary literacy.

Also, if you have a student(s) who is/are struggling to model the solar eclipse in the small group, ask if they would be willing to help demonstrate the physical model set-up with the class during the upcoming discussion.
The class can give the student(s) directions about how to hold/move the various objects/materials to represent the eclipse, and then you can follow up with these students privately after the discussion to check in on their individual understandings.

Discuss the physical models and create a classroom consensus model. Display **slide I**, and use the discussion questions listed here to come to consensus about how a solar eclipse happens.*

- *What happens with the Earth, Sun, and Moon when we see a solar eclipse? Let's describe it using words and our physical models.*
- *Why did Derek (from the video) have to travel to see the eclipse?*
- *What phase of the Moon is it when the Earth, Sun, and Moon are in those positions?*

Students can remain in their groups, as they will continue using their physical model after this discussion and after they revise their individual models. If students can quickly and easily move into a Scientists' Circle and then back into groups, this would be ideal.

Key Ideas

Purpose of this discussion: to come to consensus on how the Earth, Sun, and Moon are arranged to cause a solar eclipse

Listen for the following ideas:

- The Moon is positioned between the Sun and Earth.
- The Moon casts a shadow onto Earth.
- The Moon blocks the Sun from view for observers in that shadow.
- The Moon's shadow only falls on certain places on Earth; these are the only places where observers will be able to see the eclipse.
- When the Moon is aligned with the Sun and Earth to cause an eclipse, it is a New Moon.

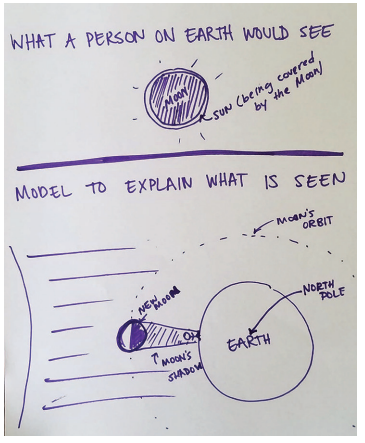
Direct students to use their physical models during this discussion to show the ideas they are explaining.

Say, *Let's take a minute and draw a model together to represent this. First, let's capture what a person would see on Earth.*

Use the chart titled "How does a solar eclipse happen?" to draw what a person would see, the class should suggest drawing the Sun blocked by the Moon. If students are struggling, ask them what Derek saw in the video. Ask students to modify their individual models *Lesson 7: My Initial Model to Explain:*_____ as the class creates a model. If students need additional space, you can have them record their updated model elsewhere in their notebooks instead of on the handout.

To create a model to explain what we see from Earth during a solar eclipse, ask, *What perspective should we take in order to see the shadow hitting the Earth?*

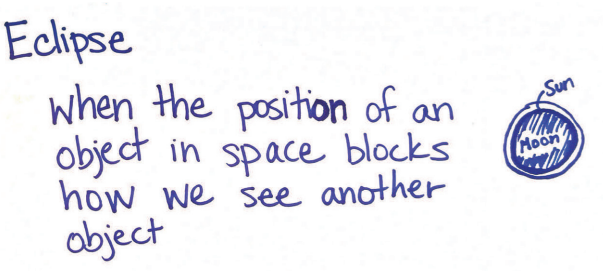
Look for students to suggest the perspective we used in the previous lesson in which we could see the Earth (looking down at the North Pole) as well as the Sun and Moon. See the example model shown here. Keep this model posted because you will want to refer to it again on day 2.



Add *eclipse* to the Word Wall. Say, *It feels like we have a deeper understanding of the word "eclipse". Let's add it to the Word Wall. Can someone suggest a definition we can use as a class?*

Listen for students to suggest a definition similar to this: when the position of an object in space blocks how we see another object. If students' definition focuses specifically on the Moon blocking the Sun, update the definition after students have explored lunar eclipses to be more general.

Additionally, you might ask if anyone has heard this word used about something other than sky-related phenomena, and the class can consider how additional uses are similar to and different from an eclipse of the Sun by the Moon.



Alternate Activity

Extension Opportunities: This lesson is focused on total solar eclipses, which are often referred to throughout the lesson as just *eclipses*. Additionally, students are asked to focus on what is happening in the path of totality, though this language is not used.

If students want to explore partial solar eclipses or what it means to be in the path of totality, they will need to investigate the way that light travels and the structure of shadows created by a sphere (i.e., the umbra and penumbra). This can be done by pointing a light at a sheet of white paper and then using a sphere to cast a shadow onto the white sheet of paper. Students should vary the distance of the paper to see that the shadow sharpens or becomes more diffused based on distance. In this process they will be able to see the umbra (the darker region of the shadow) as well as the penumbra (the less dark region). Connect this idea back to their models. What students have modeled to this point is where the umbra hits the Earth and the experience an observer would have if they were in the umbra. Students can predict what an observer would see and experience if they were in the penumbra part of the shadow, and then you can share images and descriptions so that students can check their predictions. This simulation can help students explore the umbra and penumbra, but it also includes the antumbra. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

If students want to explore annular solar eclipses, they will also need to investigate the elliptical shape of the Moon's orbit around the Earth and consider how that affects: the distance of the Moon from Earth, the apparent size of the Moon, and the resulting eclipse.

5. Navigation

5 MIN

Materials: None

Navigation. Say, *As we were updating our models, I was wondering something: We said last time that we would see each phase of the Moon about every 29 days. So, is there a solar eclipse every time there is a New Moon? Does our current model answer this question?*

Note: if there is a question on the DQB about this, point to the question as the motivation for this line of thinking. Give students time to turn and talk before sharing as a whole class.

Suggested prompts	Sample student responses
Does that mean we'll get a solar eclipse every 29 days? Every time there is a New Moon?	*It doesn't seem like there is an eclipse every month, otherwise, it probably wouldn't be such a big deal to see one.*
Does our current model answer this question?	*No, it only shows a solar eclipse occuring during a New Moon, not a New Moon without a solar eclipse.* *No, it only shows one month, not multiple months.*

Say, *Well, when we are back together next class, let's see if we can use our physical models to figure this out.*

Alternate Activity

If time permits, the video at 4.06 minutes shows a diverse set of individuals—diverse in terms of age, race, geographic location within the United States, and gender—reacting to seeing the 2017 solar eclipse. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) If you choose to watch this video with your class, skip ahead to at least 3:08 because the beginning of the video has religious references, a mention of how often eclipses occur (which students will make sense of on day 2), and use of the term *totality* which is not a concept addressed in the lesson.

End of day 1

6. Navigation and Group Modeling of New Moon without an Eclipse

15 MIN

Materials: Physically Modeling a Solar Eclipse, science notebook, *Lesson 7: My Initial Model to Explain: _____*, Day 1 Solar Eclipse Model

Navigation. Display **slide J**. Say, *When we left last class, we were wondering if there would be a solar eclipse every time there is a New Moon. It was suggested that it seems unlikely there are eclipses every month because they wouldn't be such a big deal if they occurred that often. Let's see if we can use our physical models to figure this out.*

Develop physical models in small groups. Display **slide K**. Give students 7 minutes to work with their models in groups to collaborate and figure out how there can be a New Moon but not an eclipse. If students just move the observer, say, *So in this case, this observer wouldn't see the eclipse, but what about if there was a person here* (point to a place where the observer could see the Moon)*? Is there a way for this person to experience a New Moon and no solar eclipse?*

Additional Guidance

By having the Moon on its orbit, students may be more likely to think about the plane of the orbit and its tilt, though they may not use this terminology. The only way to get the Moon to be too high, too low, or aligned is to have a tilt or to move the whole orbit up and down. Since students recently figured out that the Earth is tilted, they may be more likely to consider that the Moon's orbit could be tilted.

Walk around and listen to conversations. If you hear students struggling or leaning toward the idea that the whole orbit is moving up and down, validate their thinking that that would have the effect we are looking for, and push them to consider whether there are other possibilities.

Discuss the physical models and create a classroom consensus model that includes the Moon's tilted orbit. Display **slide L**, and check in with the whole class by posing the discussion questions on the slide and shown below. Students can remain in their groups as they will continue using their physical model in the next part of the lesson. If students can quickly and easily move into a Scientists' circle and then back into groups, this would be ideal.

Key Ideas

Purpose of this discussion: to come to consensus on how the Moon's tilted orbit affects why we don't see a solar eclipse at every New Moon.

Listen for the following ideas:

- Sometimes the Moon is too high or too low to block the Sun from Earth/cast its shadow onto Earth.
- The Moon's orbit is tilted.
- The tilted orbit of the Moon is the reason it's sometimes too low or too high to cause an eclipse.

Direct students to use their physical models during this discussion to show the ideas they are explaining.

Ask, *Did anyone find a way to model a New Moon when the observer would not see a solar eclipse?* Sample student response:

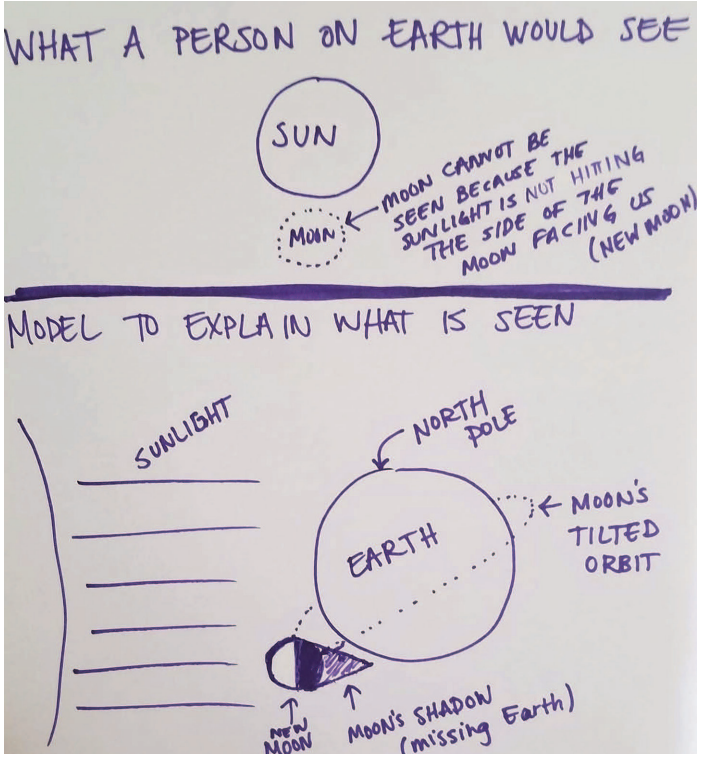
- *When the Moon is too high or low, it does not block the Sun from Earth's view, so there is no eclipse.*

Invite students to show with their models the position of the Moon up and down while they are describing it. Ask, *So if the Moon is too high or low, it won't block the Sun and cause an eclipse, but why would the Moon be too high or low sometimes and in the right spot for an eclipse at other times?* Sample student response:

- *If the Moon's orbit isn't flat, the Moon can be in different positions at different times, too high sometimes or too low at other times.*
- *The Moon's orbit is tilted or sideways.*

Invite students to show with their models the Moon's orbit to be tilted. Say, *Let's go back to the classroom consensus model—Solar Eclipses in the Earth-Sun-Moon System—that we constructed last time. We can't see the tilt of the Moon's orbit here. What can we do to show this tilt?* Look for students to suggest that we need to add an additional perspective to see the tilt.

Write the question this model is answering at the top of a new sheet of chart paper: Why don't we see a solar eclipse with every New Moon? Add a perspective of the Earth from the side that shows the tilt too high or too low and the Moon's shadow missing the Earth. Do not ask students to draw individual models, but instead have students share important things to include in this class model that you are creating together. See the example model shown here.



Wonder about how often solar eclipses can occur. Now that students have figured out that there does not have to be an eclipse every time there is a New Moon, pose the question of how often an eclipse can happen. If a question to this effect is on the DQB, point to it as the motivation for this line of thinking. If not, use this moment to problematize what we've figured out so far and push students to go deeper.

Suggested prompts	Sample student responses
We can see that an eclipse only happens when the Moon is aligned with the Sun and Earth. It has to be a New Moon but not too high or too low. How often will that actually be? How common or rare do we think solar eclipses are? Why?	*Accept all answers.*
What else have we learned about orientation or movement in the Earth-Moon-Sun system that might be important to consider?	*The movement of the Earth around the Sun might matter.*
If needed, you can look back through your science notebook for ideas.	

Say, *Let's use our physical model—with the orbital tilt—to show how New Moons can happen throughout the year.*

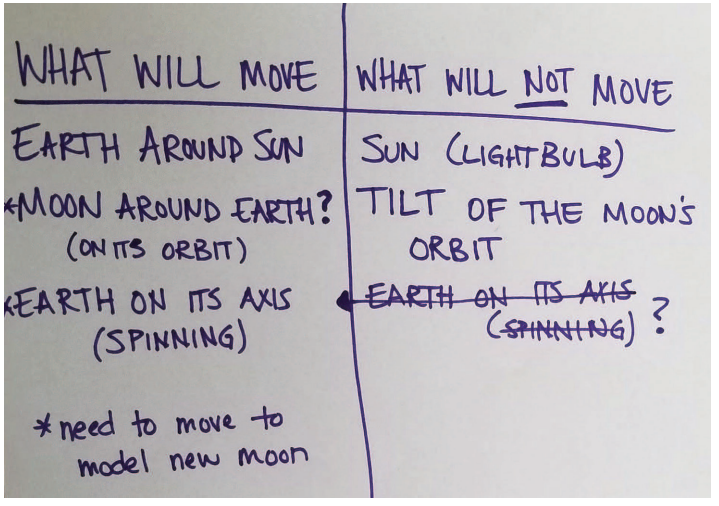
7. Model New Moons throughout the year.

18 MIN

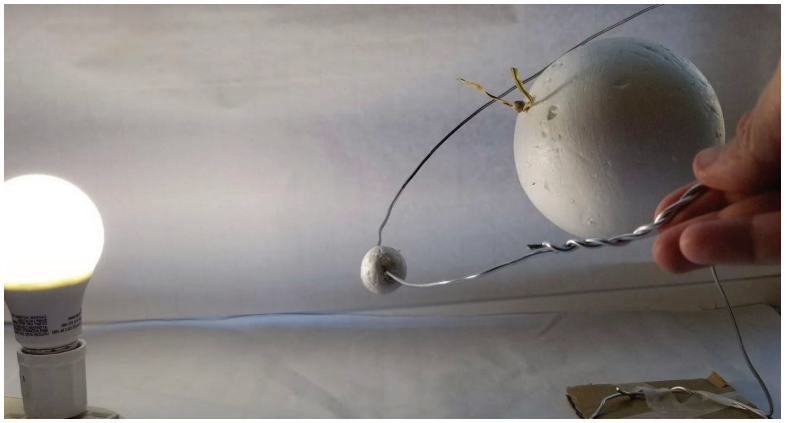
Materials: Physically Modeling a Solar Eclipse, "Important Parts and Interactions to Include in the Model" chart

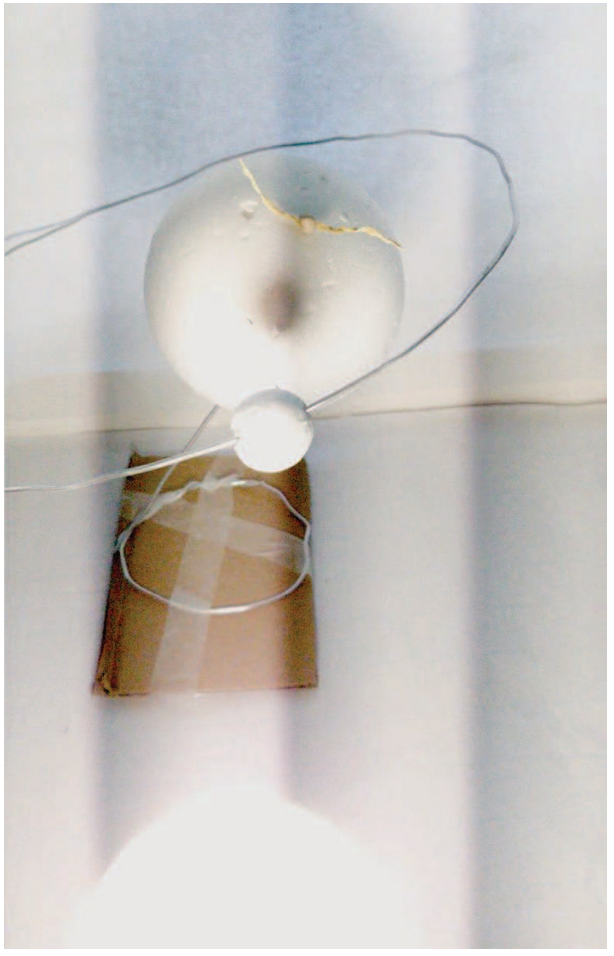
Display **slide M**. *Say, Before we start using our physical models, let's do some planning. Adding this new interaction—the Earth's movement around the Sun—will make it more complex. Let's check our* "Important Parts and Interactions to Include in the Model" chart *and also point out which components will move or not to help us keep our model as simple as possible (while still being able to help us figure this out.)*

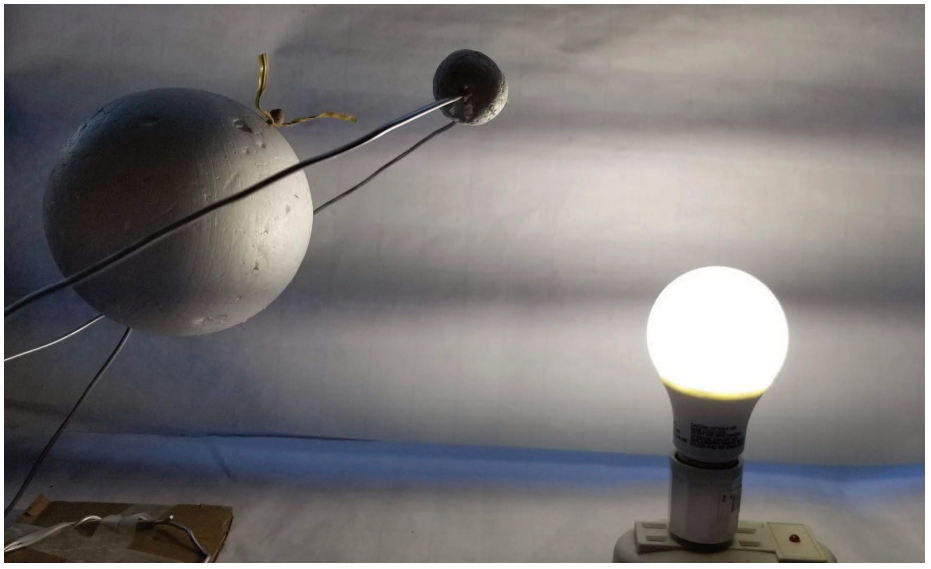
Create a list of "What will move/What will not move" at the front of the room so students can reference it when they are using their models. Refer to your previous list of components and interactions we'll have in this model and have the provided modeling supplies out if it is helpful for students to think through what will move and what will not. If students suggest adding the Earth's rotation to the list, ask, *Does this matter for what we are trying to model?* If students are unsure, add question marks to indicate that this is something we may need to try as we use our physical models and that may help us determine if it is useful. The list can be modified as students begin using the model, as shown in the example below.

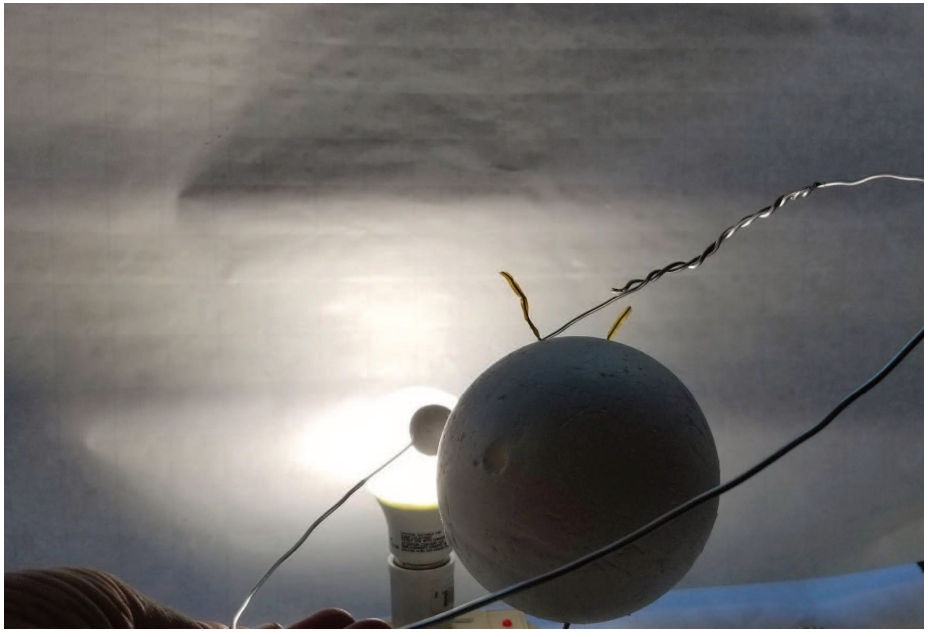


Students should figure out that the tilt of the Moon should not change. To create a New Moon at different places of Earth's orbit around the Sun, the Moon will need to move to be between the Sun and the Earth. The images below show the tilt of the Moon remaining constant, but the location of the Moon on its tilted orbit changing to always have a New Moon regardless of where the Earth is on its cycle around the Sun.









Allow students to try to physically manipulate the model to show New Moons as seen by Earth in various positions around the Sun as they did in Lesson 4 when they made sense of temperature variation. If you notice students moving things in a way that doesn't correspond with the list, say, *Tell me about how you are moving your model*, and analyze together if it aligns with the list and what we know about movement of the Sun, Earth, and Moon.

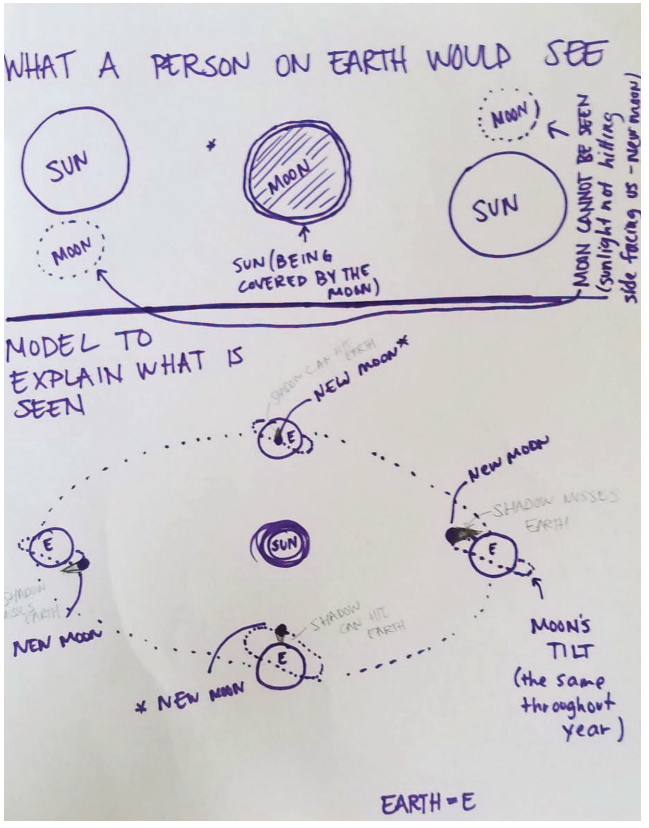
Add another additional perspective to the classroom consensus model of solar eclipses. Display **slide N**. Say, *Let's go back to our classroom consensus model one more time—we have already recorded our ideas about how solar eclipses happen and why we don't see one at every New Moon. But, will these models allow us to show what we just figured out about how often solar eclipses can happen? (No.)*

Ask, *What's missing from the models we already have? What do we need to do differently?*

Sample student responses:

- *We need to show the Earth in multiple locations around the Sun.*
- *We need to show its movement and position around the Sun throughout the year.*

Title a piece of chart paper with the question, "How often could we see a solar eclipse?" Work with students to develop a third classroom consensus model with the Earth at four locations around the Sun (as in Lesson 4). Be sure to include the Moon's tilted orbit—at the same angle at each of the four locations—and to place the Moon on orbit where it will be between the Sun and Earth. Do not ask students to draw individual models, but instead have students share out important things to include in the classroom consensus model, and then represent them at the front of the room. See the example model shown at right.



Summarize by asking, *What do the models we have developed—this model and our physical models—tell us about how often a solar eclipse is likely to occur?* Students should indicate that our models show that the alignment of the Sun-Earth-Moon system can result in a total solar eclipse two times a year.

Additional Guidance

There are other factors that can affect whether people will see a total solar eclipse, such as whether the shadow hits the ocean or if the distance of the Moon is such that it doesn't fully cover the Sun, but these are beyond the scope of this unit. If students bring up questions about this, it's okay to wonder together: *Just because we know a solar eclipse could be seen twice a year, does that mean that people can always see it twice a year?* If time allows, you can do some thought experiments about that, and leave it as something worth investigating more in the future. For more specific extension ideas, see the Alternate Activity box earlier in this lesson.

8. Update Progress Trackers.

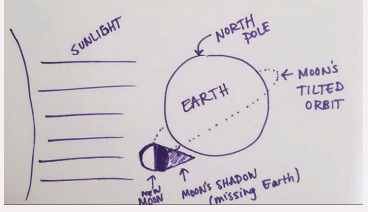
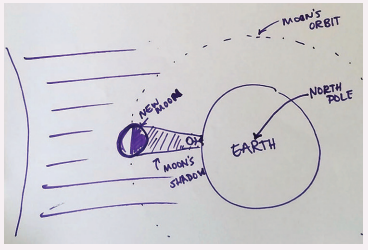
5 MIN

Materials: science notebook

Update Progress Trackers to reflect new understandings. Present **slide O** and ask, *What new interactions should we include in our Progress Tracker?** Sample student responses:

- *The Moon can block the Sun, causing a solar eclipse. This can happen during a New Moon.*
- *Because of the tilt of the Moon's orbit, the Moon can sometimes be too high or too low to cause an eclipse, so not every New Moon causes a solar eclipse.*
- *The Moon, Earth, and Sun align in such a way that a solar eclipse can occur twice a year.*

Have students update their models and add their new understandings to their Progress Trackers.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
Why do we see eclipses, and when do we see them?	Solar eclipses occur when the Moon blocks the Sun and the resulting shadow hits the Earth. If an observer is in the shadow, they will see the eclipse.  A Solar eclipse happens when there is a New Moon that is not too high or too low on its orbital tilt. 	Answers will vary, but some sample ideas could include: • Eclipses are considered sacred by some communities. • We can predict when, we will get a chance to see an eclipse. • Solar eclipses are not very common, so it's cool when we get a chance to see one!

*** Attending to Equity**

Universal Design for Learning: Some students may benefit from using other modalities, such as explaining using the physical model, to ***express*** their understanding of the cause of solar eclipses. You may consider allowing some students to present their answers verbally with you and then scribe their thinking on paper or to create short videos while using physical models. These options might allow students to also use gestures to help articulate and explain their understanding about how the positions of objects in the Earth-Sun-Moon system change the patterns we see in the sky. Encouraging students to use other modalities to show their thinking creates an equitable pathway for all students to demonstrate proficiency.

Additional Guidance

You may also want students to update their Progress Trackers with what they figured out about the phases of the Moon from the previous lesson.

9. Reflect on Model Boundaries Discussion.

5 MIN

Materials: *Lesson 7: Self-Assessment for Collaborative Group Work*, Class consensus model



Reflect on model boundaries and limitations. Display **slide P.** Guide students through a reflection on the modeling they've done in this lesson.* The purpose of this conversation is to recognize that there are a lot of components, movements, and interactions in the solar system—and subsystems of the solar system—and that it's hard to show and process all of these things all of the time. Because of this complexity, we focus on what is helpful at any given point while acknowledging that we are leaving things out. The three models we created were as follows:

1. Model of "How does a solar eclipse happen?"
2. Model of "Why do we not see a solar eclipse with every New Moon?"
3. Model of "How often might we see a solar eclipse?"

Say, *This model—"How often might we see a solar eclipse?"—looks pretty different from our first model "How does a solar eclipse happen?" Does that mean that our first model was wrong? (No!)* Use prompts such as the following to support students in continuing to compare and contrast these various iterations of the Earth-Sun-Moon system model.

- *How did the parts and interactions in each of these models connect with each of the questions we were trying to figure out?*
- *What are some parts and interactions we didn't include in each model? Why did we leave those things out?*

*** Supporting Students in Developing and Using Systems and System Models**

During this discussion, students collaborate to build understandings about the boundaries and limitations of their models. They have a chance to reflect on the reasons they included or did not include certain components or interactions in the Earth-Sun-Moon system, and what representation was most helpful for developing certain ideas and why. Support students in recognizing how their models only need to represent the aspects of the system they're trying to figure out.

Key Ideas

Purpose of this discussion: Reflect on the various models we've developed to explain solar eclipses in this lesson and build understandings about the limitations of models in representing all aspects of the Earth-Sun-Moon system.

Listen for these ideas:

- We only included the pieces/components/interactions we needed to answer our specific questions.
- Our model of "How does a solar eclipse happen?" only needed the Sun, Moon, and Earth because we only needed to explain how those objects interact to cause a solar eclipse.
  - This model did not include the tilt of the Moon's orbit, but that was OK when we were just trying to understand how a shadow could be cast on Earth.

- Our model of "Why don't we see a solar eclipse with every New Moon?" had to include and use the tilt of the Moon's orbit to show how the Moon could be too high or too low, even when the Moon was between the Earth and Sun (i.e., a New Moon).
  - Our first model did not help us explain why we didn't see a solar eclipse every month.
  - This model and the first one did not include the Earth's movement around the Sun because that wasn't necessary until we wondered how often we'd see an eclipse.
- Our model of "How often might we see a solar eclipse?" had to include the movement of the Earth around the Sun.
- We had to change perspectives in each of these models to show both what an observer would see and why. One perspective is not able to show both of these things.
- Using physical models allows us to move the components around and try different ideas to see how the parts interact. But it's hard to show multiple positions/situations at once with a physical model.
- Drawn models help us show multiple perspectives at once. We can also include written descriptions in drawn models, and we can easily keep them to refer back to. But they do not let us manipulate objects and their motions and interactions to test our ideas as easily as the physical model does.

Students may mention other limitations or things that were not within the boundaries of these models. For example, by putting the Moon on the orbit wire, they could not keep the lit side of the Moon consistent, but again this was not necessary to understand eclipses.

If time permits, students can complete *Lesson 7: Self-Assessment for Collaborative Group Work* as part of their reflection.

Assessment Opportunity

Building towards: 7.A Develop and use a model of the Earth-Sun-Moon system to explain why and when eclipses can be seen.

What to look/listen for: Refer to the key ideas listed in the previous box.

What to do: If students are not connecting the parts and interactions of each model to the purpose, walk back through the process the class took to create each model. For example, once the class figured out a solar eclipse could occur when there is a New Moon, the question of whether there is a solar eclipse every New Moon came up. The class recognized that the model they had created at that point—"How does a solar eclipse happen?"—did not answer the new question, and so they needed to create a new one with new components and interactions.

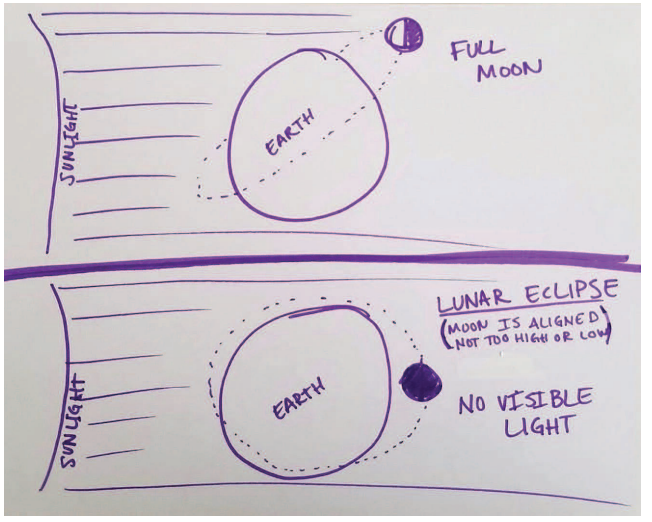
If students are not recognizing the need for multiple perspectives, refer to a perspective that shows what a person sees and ask, *Does this explain why an observer would/would not see an eclipse?*

10. Navigation

7 MIN

Materials: chart paper

Develop a classroom consensus model to Predict Lunar Eclipses. Display **slide Q**. Using the physical model for demonstration, move the Moon to be a full Moon instead of a New Moon (i.e., for the Earth to be between the Moon and Sun). Point out that it can also be too high, too low, or aligned, just like the New Moon. Ask, *What do you think a person on Earth would see when the Moon is full and aligned with the Earth and Sun? Why?* Give students a minute or two to turn and talk.



Do not ask students to draw individual models, but instead have students share out important things to include in the model, and then represent them in a classroom consensus model at the front of the room.

Sample student responses/ideas to include in your classroom consensus model:

- When the Earth, Sun, and full Moon are aligned, the Moon will not be visible.
- Earth will be blocking sunlight from hitting the Moon, and therefore it will not be illuminated or visible.

Say, *We've been figuring out why and when solar eclipses occur. The situation we're modeling now causes a lunar eclipse.*

See the sample classroom consensus model shown here predicting what we would see during a lunar eclipse and why.

Title this model with the question "What causes a lunar eclipse and what would people see from Earth?"

Say, *Next time, let's explore lunar eclipses and see if we can figure out if our prediction was correct.*

SCIENCE LITERACY: READING COLLECTION 2

Reaching for the Moon

1 ***Le Voyage dans la Lune***
2 **The Space Race**
3 **Consider the Evidence**
4 **Script versus Transcript**

Literacy Objectives

- ✓ Summarize key points gleaned from reading.
- ✓ Distinguish between credible and non-credible sources.
- ✓ Differentiate fact, reasoned judgment, speculation, and opinion.

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 5–7.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a social media post in response to the reading.

Instructional Resources

Student Reader



Collection 2

Science Literacy Student Reader, Collection 2
"Reaching for the Moon"

Exercise Page



EP 2

Science Literacy Exercise Page
EP 2

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 5: How can we explain phenomena like Manhattanhenge?
- Lesson 6: Why do we see the shape of the Moon change?
- Lesson 7: Why do we see eclipses and when do we see them?

Standards and Dimensions

NGSS

Disciplinary Core Ideas: ESS1.B: Earth and the Solar System The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year. (5-ESS1-2)

ETS1.C: Optimizing the Design Solution The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (MS-ETS1-4)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Cause and Effect; Connections to Engineering, Technology, and Applications of Science

CCSS

English Language Arts

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

RST.6-8.10: By the end of grade 8, read and comprehend science/technical texts in the grades 6-8 text complexity band independently and proficiently.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

orbit

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

artificial satellite

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Earth in Space unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *What could a French foreign film have to do with understanding the moon? You will find out when you read about the 1902 film called* Le Voyage dans la Lune.
  - *Next, you'll interpret a timeline of the 20th-century space race between the Soviet Union and the United States. See if you think there was a clear winner.*
  - *Then, you'll read a mock social media debate about whether NASA's 1969 landing on the moon was faked or real.*

- *Finally, you'll read a simulated script of a scene from a more recent film about the Apollo moon landing and compare it to the transcript from the actual mission.*

- Distribute Exercise Page 2. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a social media post to share something interesting you read from Collection 2.*

Exercise Page



EP 2

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How was the spacecraft in the French film titled Le Voyage dans la Lune *powered?*	*It was launched from a cannon on Earth.*
What two political states raced one another into space in the 20th century?	*the US and the USSR*
If you take a photo of people on the moon during the daytime, how does the sky behind them look?	*It looks black without any stars, etc.*
What are two reasons human space travel beyond Earth orbit did not occur in the 50 years after the humans first landed on the moon?	*It is dangerous and expensive.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does the reading about the French film connect to the historic representations of the moon we discussed in Lesson 6?	*It confirms that people have been looking at the moon for a long time.*
What "orbits" were discussed in the Space Race timeline? What orbits did we explore in Lessons 6 and 7?	*The timeline talked about the orbit of artificial satellites around Earth, and in Lessons 6 and 7 we talked about the moon's orbit around Earth and Earth's orbit around the sun.*
Picture your models of a total solar eclipse. If astronauts are on the daytime side of the moon while people were seeing a total solar eclipse from Earth, could they see Earth? Explain.	*probably not, because the daytime side of the moon would be facing the sun, not Earth*

- Refer students to the Exercise Page 2. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to create a mock social media post in which you share one interesting thing you learned from reading Collection 2 and explain why you found it interesting.*
  - *Make your post as engaging as you can, but do use standard English instead of text and social media acronyms.*
  - *Create a hashtag that is easy to read and will attract others to respond.*
  - *Try adding a question that will engage your followers in a conversation.*
  - *The important criteria for your work are that you state the fact you share accurately and that you use all the elements of an engaging social media post.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 2

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. Since humans have spent thousands of years looking at and trying to explain sky patterns related to the moon, isn't it natural that they would go to great effort to develop engineering systems to place humans on the moon? That is what this collection is about—getting humans to the moon.

Student Reader



Collection 2

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Pages 14–23 Suggested prompts	Sample student responses
*What is the general purpose of the first selection, "*Le Voyage dans la Lune*"?*	*It describes a French science fiction film, made in 1902, about astronomers who journey to the moon and what they find there.*
What did the author mean by saying the film was meant to be "satire"?	*Satires make fun of people or situations. The filmmaker must have thought that humans traveling to the moon was impossible or silly.*
In Collection 1, you read a selection called "Celestial Stories." Which one of those ancient stories relates closely to the depiction of the moon in the film?	*The Aztec story about why people see a picture of a rabbit when they look at the face of the moon is similar to the idea from the film that the moon face looks like a man's face.*
What is the general purpose of the second selection, "The Space Race"?	*It is a timeline that describes the competition between the US and USSR to explore space.*
What are "artificial satellites," as mentioned in the timeline?	*any satellite that was made by humans*
Why did the US and USSR launch dogs or chimpanzees before they launched humans, and what do you think about this?	*Maybe leaders in these countries thought that if they first launched humans and the humans were killed, citizens would try to stop the space race.* *Scientists still do experiments on other animals, and it doesn't seem fair to the animals. However, it is a way to help humans.* *Humans use animals for many purposes that harm the animals, including using them as food.*
What would you say to the filmmaker who made Le Voyage dans la Lune *after reading this selection?*	*I'd say, "You got it wrong! Just 67 years after you made the film, scientists did launch a spacecraft to the moon carrying people who explored the surface and returned to Earth."*
What is the general purpose of the third article, "Consider the Evidence"?	*It is an argument among a group of people about whether humans actually went to the moon or not.*
What three questions do the posters who are skeptical ask?	*Why aren't stars in the sky in the photo of the moon landing? Why do the shadows point in different directions in the photos? How could the astronauts survive harmful radiation?*

Online Resources



SUPPORT—Filmmaking is a scientific and technical art that evolved as inventions enabled recording of images, the addition of color, sound, and large-screen and 3-D formats. Have students explore websites that describe the history of filmmaking, and ask them to place *Le Voyage dans la Lune* in a simple timeline.

EXTEND—Students may enjoy watching *Le Voyage dans la Lune* online, where it can be found set to music. Point out that in the early days of film, there was no sound, so stories were acted out in pantomime, and theaters often provided live musical accompaniment to support the story shown on screen.

Pages 14–23 Suggested prompts	Sample student responses
Why do you think the author chose to write this selection as a social media discussion?	*because these arguments take place all the time online* *to remind us that people can discuss controversies online and still be polite to one another*
Look at the "Spot the BS" box. Can you detect where the reasoning and science don't quite add up?	*Andy may not know that stars seen from Earth are very dim so the pupils in your eyes have to open very wide to see them. Likewise, camera settings for a brightly lit object in the foreground may mean that dim objects in the background cannot be captured in the same photo.*
Check out the "Consider the Source" box. Of the various responders, who constructs theories from their own personal viewpoints, and who provides more credible information?	*Andy and Danica seem to have personal viewpoints.* *Wendy is using her knowledge as a medical doctor but doesn't have the whole story.* *Micheala, K.S. Field, and Alicia seem to have credible scientific explanations.*
What is the general purpose of the fourth article, "Script versus Transcript"?	*It provides a fictional and real version of the words spoken during the Apollo 11 lunar landing for the reader to compare and contrast.*
How is the screenplay different from the transcript?	*It's shorter. There is less dialogue.*
Why do you think the author of the screenplay made it different from the transcript?	*The screenplay dialogue, especially the part about the world watching and the thumbs-up, is more dramatic and suitable for a movie.* *Some of the spoken descriptions could just be shown as action in the movie.*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 2, students should create a social media post to summarize something interesting they learned in Collection 2 and explain why it intrigued them. The criteria for their post are the number of characters expected, inclusion of an image from one of the readings, and creating a hashtag that others can use to continue to the conversation.

Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 8

What does a lunar eclipse look like and how can we explain it?

Previous Lesson

We watched a video of a solar eclipse. We explained what we saw in the video using a physical model of the system and a drawn model using multiple perspectives. We returned to our physical models to figure out why we do not see a solar eclipse every month and how often we might expect to see one.

This Lesson

Problematizing

1 DAY



We analyze images of lunar eclipses and compare them to the lunar eclipse predictive model we made as a class in Lesson 7. The reddish color of the Moon that we observe during a lunar eclipse is unexpected. So we list possible causes of that reddish color and gather examples of related phenomena of objects reddening in the sky. After posting our color-related questions, we generate ideas for investigating them.

Nex t Lesson

We will examine images of the Sun and Moon at different times of day, examine diagrams of the atmosphere, and observe images of the Sun through the atmosphere and from the ISS (above the atmosphere). We will revise our model and predict that the amount of atmosphere the light travels through affects the difference in color we see at sunrise compared to midday.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

8.A Evaluate the limitations of our system model predicting what we would see during a lunar eclipse.

What Students Will Figure Out

- The Moon is full during a lunar eclipse; this is what our model predicted.
- The Moon turns reddish and dimmer (still visible) during a lunar eclipse but does not become completely dark (not visible); this is not what our model predicted.
- There are other times when we have experienced the Moon or Sun changing color like this (to reddish or orange).

Lesson 8 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION** Revisit the class model created in Lesson 7 to make predictions about what a person would see in the sky when watching a lunar eclipse.	A	*Analyzing Lunar Eclipse Images*, tape, class model to predict a lunar eclipse (from Lesson 7)
2	10 min	**ANALYZE LUNAR ECLIPSE IMAGES** Work independently and then in partnerships to analyze images of lunar eclipses comparing them to the predictions we made from our model.	B-V	*Analyzing Lunar Eclipse Images*, Student Images of Lunar Eclipse Slides, *Lunar Eclipse Images* (optional)
3	8 min	**SHARE WHAT OUR MODEL DID AND DID NOT PREDICT ABOUT LUNAR ECLIPSES** Lead a Building Understandings Discussion about what students figured out about lunar eclipses from comparing their model predictions to eclipse images, and then hold an Initial Ideas Discussion to list possible causes of the reddish color seen during a lunar eclipse.	W–X	class model to predict a lunar eclipse (from Lesson 7)
4	5 min	**SHARE RELATED PHENOMENA** Gather examples of other times students have seen or heard about the Moon or Sun (or other things in the sky) changing color.	Y	chart paper and markers
5	8 min	**REVISIT OUR DQB TO TAKE STOCK OF COLOR QUESTIONS** Record new questions about these color-changing phenomena, post those and the color-related questions we already had on the DQB on our new Color Changes poster.	Z	sticky notes or index cards, Color Changes poster (created in part 4), Driving Question Board
6	9 min	**PLAN NEXT STEPS** Recall tools we've used previously in this unit to help us generate ideas for investigating our color-related questions. Assign optional home learning to collect local data about the color and brightness of the Sun at different times of day.	AA-BB	optional *Home Learning: Sunset Brightness and Color Data Collection* or optional *Home Learning: Choice Brightness / Color Data Collection*

End of day 1

Lesson 8 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Analyzing Lunar Eclipse Images* • science notebook • tape • optional *Home Learning: Sunset Brightness and Color Data Collection* or optional *Home Learning: Choice Brightness / Color Data Collection*	• Student Images of Lunar Eclipse Slides • *Lunar Eclipse Images* (optional)	• class model to predict a lunar eclipse (from Lesson 7) • chart paper and markers • sticky notes or index cards Color Changes poster (created in part 4) • Driving Question Board

Materials preparation (20 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Reminder about supporting students with visual disabilities: This unit uses images as data. Specifically in this lesson, students analyze color images of lunar eclipses to problematize that our model predicting how a lunar eclipse would look did not predict that the Moon looks reddish in color during a total lunar eclipse. Students who are color blind will usually be able to identify that the color of the Moon during the total eclipse is different from the "dark" they predicted (although they may or may not identify that different color as "reddish"); however, students with monochromacy/achromatopsia will likely not be able to recognise the color change. So, you will need to make accommodations so that students with this and other visual disabilities can access this data. Depending on your students' needs, suggested modifications include enlarging and/or brightening the provided digital versions of these photos or using alternate text descriptions.

Plan how students will access the *Student Images of Lunar Eclipse Slides* for part 2 of this lesson—this file is available from the *Student Images of Lunar Eclipse Slides*. Ideally you can digitally share this slide deck with student partnerships so they can work together to sequence the out-of-order images. If you are not able to share that slide deck digitally with students or if time is short, here are some other options:

- Instead of sequencing the out-of-order slides, students can observe the lunar eclipse images in chronological order with *Lunar Eclipse Images*. This reference is available in the Student Edition. Alternatively, if you are able to print copies in color, you could provide *Reference: Lunar Eclipse Images* as a handout; black-and-white printed copies will not work.
- You could print color copies of the *Student Images of Lunar Eclipse Slides* or *Reference: Lunar Eclipse Images* and cut the images apart to use as a physical card-sort for partnerships. If you have several classes that will use these cards, you may choose to laminate them as well, and have students reshuffle them out of order again at the end of class for the next group to use.
- You could observe the lunar eclipse images together as a whole group. The class can work together to sequence the out-of-order *Student Images of Lunar Eclipse Slides* or simply advance through the correctly sequenced **slides C–Q** of the Lesson 8 slides.

If you are planning to have students do the optional local light data collection for the Home Learning in this lesson, they will need access to a device with a camera and light meter app. Smartphones work well and school-supplied tablets or Chromebooks can also work, but you would likely need to ask your school's technology department to install a light meter app on school devices. Also, you will want to either share *Home Learning: Sunset Brightness and Color Data Collection* with students digitally or set up another way for students to collect their data, such as a shared slide deck. Finally, plan whether your class will collect only the data suggested on the handout (monitoring the brightness of the Sun/sky around sunset) or take part in other inspiring opportunities listed in the guidance in part 6 of this lesson. Either way, provide time later in the unit for students to share and discuss their data. For example, consider replacing some of all of the photos used in part 2 of Lesson 9 with student-provided photos of sunsets, and possibly sunrises, moonrises, and moonsets, if available.

Lesson 8 • Where We Are Going and NOT Going

Where We Are Going

Lesson 8 launches this unit's Lesson Set 3, where students will investigate phenomena that necessitate developing a model of light that can account for changes in color and brightness when it interacts with matter. These explorations are motivated by relatively common experiences here on Earth of when we see changes in the color and intensity of objects in space, such as the Sun and Moon, when the light from them passes through different amounts of our atmosphere.

This Earth-bound perspective helps keep this content relevant for students. However, the atmospheric model we develop by Lesson 12 to explain the color changes we see in the Moon and Sun will not explain some of students' other possible color-related questions (such as the variety of colors of stars or the colors of different planets, neither of which have to do with how we see them through our atmosphere). We want to avoid setting students up with a misconception that refraction of light in our atmosphere is the reason for all colors/color changes we see in space. It's possible that some student questions that remain after this lesson set will need to be put "on hold" until high school, where the emission spectrum of elements will be explored. However, considering our location here under the atmosphere will help motivate students' wondering about how we can explore space beyond our atmosphere (via telescopes on mountains, as satellites, etc.) in Lesson 13. More direction about how to navigate the tricky path of explaining some, but not all, of our color-related phenomena is provided in the Lesson 12 *Teacher Guide*.

Through this lesson set, students will establish that their lunar eclipse model represents the Earth-Sun-Moon system and that the matter in Earth's atmosphere selectively absorbs and bends light from the Sun to color the Moon red, so they will revise their drawn model to include this aspect of the system. While students will be able to explain how the atmosphere bends light using other physical models, their three-dimensional physical model of the Earth-Sun-Moon system will not include a physical representation of that particular component. That component will only be represented diagramatically in two dimensions.

Lesson 8 specifically will re-anchor this Lesson Set 3 in figuring out why the Moon looks red during a lunar eclipse. We problematize this situation when students predict what they expect to see from the class consensus model of eclipses and then analyze images of lunar eclipses and are surprised by the red/orange color of the Moon. After gathering related phenomena and proposing possible causes for color changes like this, students suggest ideas for investigation, which then drive the rest of Lesson Set 3.

If you have students who are color blind, this color-focused Lesson Set (Lessons 8–12) may pose a unique challenge. If you haven't already done so, take some time to talk with your student(s), familiarizing yourself with their way(s) of seeing the world and asking how you can best support them as they investigate why we see objects in the sky change color. Your students' IEP or 504 case leaders should also be able to provide you with specific resources and possible modifications to use.

Note that the home learning data collection task suggested at the end of step 6 is optional. Collecting this local data set is not critical to moving forward in the unit, but there are many benefits to having students (and possibly their families) work to collect data outside school, and the suggestions provided will enrich students' experiences.

Where We Are NOT Going

Since Lesson 8 is a problematizing lesson, we will not be constructing explanations for the questions we surface today. The work students do in this lesson will motivate their work in Lessons 9–12.

Our work with lunar eclipses today and in this lesson set focuses on total eclipses. Students do not explore partial or penumbral lunar eclipses.

LEARNING PLAN FOR LESSON 8

1. Navigation

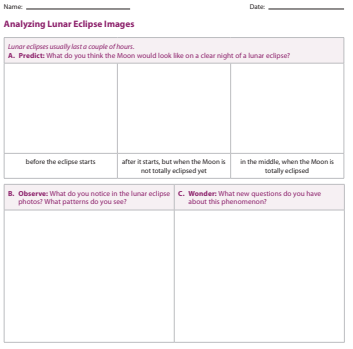
5 MIN

Materials: *Analyzing Lunar Eclipse Images*, science notebook, tape, class model to predict a lunar eclipse (from Lesson 7)

Alternate Activity

If you learned in preparation for Lesson 7 that any of your students will also opt out of viewing the lunar eclipse images in this lesson (because of their cultural beliefs about eclipses), you may problematize the idea of things in the sky changing color with sunsets instead. Provide an image of a sunset such as those provided in the Lesson 9 slides to notice and wonder about, and proceed with the related phenomena gathering in part 4 of this lesson.

Recall what we predicted last time about lunar eclipses. Display **slide A**. Distribute *Analyzing Lunar Eclipse Images* and direct students to tape it into their science notebooks. Refer to the class model to predict a lunar eclipse from Lesson 7. See the example model shown here, although your class model may look different


Name: _____ Date: _____

Analyzing Lunar Eclipse Images

Lunar eclipses usually last a couple of hours.

A. Predict: What do you think the Moon would look like on a clear night of a lunar eclipse?

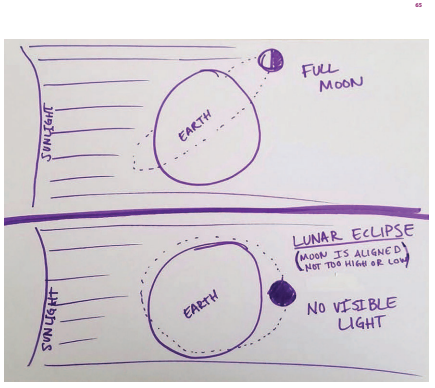
before the eclipse starts	after it starts, but when the Moon is not totally eclipsed yet	in the middle, when the Moon is totally eclipsed

B. Observe: What do you notice in the lunar eclipse photos? What patterns do you see?	**C. Wonder:** What new questions do you have about this phenomenon?

Say, *We figured out a lot about eclipses last time we were together, and we got to see a video of a solar eclipse. But we haven't yet seen a lunar eclipse, so let's investigate that today. Using the model we made last time to help you predict, what do you think we would see in the sky if you were outside watching a lunar eclipse as it occured? A lunar eclipse typically lasts a couple of hours from start to finish. What do you think you would see right before it starts, shortly after it starts, and then in the middle, when the Moon is totally eclipsed? Take a few moments to sketch and/or write your ideas in Part A of the Analyzing Lunar Eclipse Images handout in your science notebook.*****

While students record their ideas, circulate and look for ideas you would like to call attention to when students share.

After a minute or so of writing time, ask a few students to share their predictions. Suggest that the class consider whether they agree with the predictions their classmates share, and if so, they could add them to their notebook (if they don't already have those ideas).



Sample student predictions about a lunar eclipse include:

- *It should occur 15 days before or after a solar eclipse.*
- *It will only occur on a full Moon night.*
- *The Moon will gradually darken.*
- *The Moon will get covered with shadow from one side.*
- *The Moon will be completely dark and not be visible for a time.*
- *The shadow will pass to the other side and the Moon will get brighter again.*

*** Supporting Students in Engaging in Developing and Using Models**

When students use their model to predict what a person would see when observing a lunar eclipse, they are truly engaging in the practice of modeling—they are using this model as a tool for reasoning, in service of making sense of this phenomenon.

Navigate to today's work. Say, *It sounds like using our model helped us develop some great ideas about what it would be like to watch a lunar eclipse. I hope we all get to do that in real life sometime. For now, I have a series of images for us to investigate that show all of the stages of a lunar eclipse.*

2. Analyze lunar eclipse images.

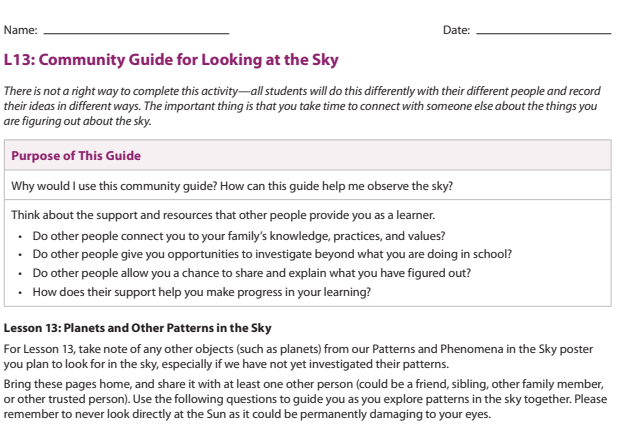
10 MIN

Materials: science notebook, *Analyzing Lunar Eclipse Images*, Student Images of Lunar Eclipse Slides, *Lunar Eclipse Images* (optional)

Work with a partner to sequence lunar eclipse images. Display **slide B.** Introduce the series of lunar eclipse images. Share details such as the following:

- The lunar eclipse captured in the images we'll use today happened on July 28, 2018. It was unusually long. The Moon was totally eclipsed for 1 hour and 43 minutes.
- These still images were captured at various intervals from a time-lapse video (see link) created by a professional astrophotographer named Kwon O Chul. He lives in Korea but traveled to Uzbekistan to photograph this lunar eclipse.

Share the *Student Images of Lunar Eclipse Slides* with your students so they can access them in their partnerships. The images in this deck are out of order, and taking the time to put them into sequential order will give your students a chance to review what they've figured out in previous lessons about the path of the Moon through the sky and into and out of Earth's shadow.



Name: _____ Date: _____

L13: Community Guide for Looking at the Sky

There is not a right way to complete this activity—all students will do this differently with their different people and record their ideas in different ways. The important thing is that you take time to connect with someone else about the things you are figuring out about the sky.

Purpose of This Guide

Why would I use this community guide? How can this guide help me observe the sky?

Think about the support and resources that other people provide you as a learner.

- Do other people connect you to your family's knowledge, practices, and values?
- Do other people give you opportunities to investigate beyond what you are doing in school?
- Do other people allow you a chance to share and explain what you have figured out?
- How does their support help you make progress in your learning?

Lesson 13: Planets and Other Patterns in the Sky

For Lesson 13, take note of any other objects (such as planets) from our Patterns and Phenomena in the Sky poster you plan to look for in the sky, especially if we have not yet investigated their patterns.

Bring these pages home, and share it with at least one other person (could be a friend, sibling, other family member, or other trusted person). Use the following questions to guide you as you explore patterns in the sky together. Please remember to never look directly at the Sun as it could be permanently damaging to your eyes.

Suggest that students try viewing the slide deck in grid view to make it easier to see more images at one time. Give partnerships a couple of minutes to drag the images into the sequential order that they think makes sense, based on what they already know.

As partnerships finish organizing the images, pair them with another partnership to check each other's work. You may refer students to the Earth-Sun-Moon system models they've used in previous lessons to justify their decisions about the order of the images.

If needed, **slide R** or *Lunar Eclipse Images* can be used as a key showing the correct sequence of images. Note that the timestamps included with the images are estimates, and use Coordinated Universal Time (UTC) – the time standard commonly used across the world.

Alternate Activity

If time is short, instead of sequencing the out-of-order slides, students can observe the lunar eclipse images in sequential order with *Lunar Eclipse Images* (available in the Student Edition) or color print copies of *Reference: Lunar Eclipse Images* (see Materials Preparation section for details). Another option is to observe the lunar eclipse images together as a whole group. The class can work together to sequence the out-of-order *Student Images of Lunar Eclipse Slides* or simply advance through the correctly sequenced **slides C–Q** of the Lesson 8 slides.

If you and your class are interested in watching the time-lapse video source of these images, it is available at online, also linked on **slide S**. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Analyze the lunar eclipse images. Display **slide T.** Give students a few minutes to work with their partners and record their ideas in parts B and C on *Analyzing Lunar Eclipse Images* in their notebooks. The guiding questions on the slide and handout are:

- *What do you notice in the lunar eclipse photos?*
- *What patterns do you see?*
- *What new questions do you have about this phenomenon?*

Compare observations with predictions. Switch to **slide U** and prompt students to find discrepancies between our actual observations and the predictions we made from our model. Direct students to record their ideas on parts D and E on the handout in their notebooks.

Display **slide V**. Ask students to discuss possible causes/mechanisms for the parts of this phenomenon their model did not predict and they can't (yet) explain. Have students record their ideas in their science notebooks (or on the handout, Part F).



Assessment Opportunity

Building towards: 8.A Evaluate the limitations of our system model predicting what we would see during a lunar eclipse.

What to look/listen for:

- While students are sharing ideas with a partner, listen for them to mention ideas such as the following:
  - Our model predicted that the Moon would get darker; it did get dimmer, but not exactly how we thought.
  - Our model predicted that the darkness or shadow would move from one side of the Moon to the other; it did.
  - Our model predicted that the eclipse would only happen during a full Moon; it did.
  - Our model predicted that the Moon would not be visible when the Moon was totally in Earth's shadow, but it was visible (just dimmer and reddish!).
  - Our model did not predict that the Moon would turn reddish.

What to do: While you circulate listening to partner talk, consider taking note when you hear disagreement or bewilderment and ask, *Would you share that idea during our whole-class discussion so we can all wrestle with it together?*

If students struggle to make connections between their predictions and the lunar eclipse images, refer partnerships back to the manipulatives they used to construct their physical models of an eclipse. Guide them in modeling the relative positions of the Earth, Sun, and Moon that coincide with the images they're analyzing. For each image, ask, *Is this how you expected the Moon to look? Why or why not?*

3. Share what our model did and did not predict about lunar eclipses. 8 MIN

Materials: class model to predict a lunar eclipse (from Lesson 7)

Lead a Building Understandings Discussion about what our model predicted or not. Display **slide W**. Convene a Scientists Circle and refer to your classroom consensus model of eclipses. During this discussion, encourage students to use their science notebooks as references and allow them to refer back to specific images from *Lunar Eclipse Images*. You may also want to flip back to **slides R or S** to reference those lunar eclipse images during your discussion.

Additional Guidance

For the sake of consistency in this teacher guide, we call the color of the Moon during a lunar eclipse "reddish." You and your students should use the language and descriptions that make sense to you.

Key Ideas

Purpose of this discussion: Build understanding about lunar eclipses by comparing what we noticed in images of them to what we predicted about them from our model. Also, problematize the idea that our model of the Earth-Sun-Moon system did not predict the reddish color of the Moon during the eclipse. Why is that happening?

Listen for these ideas:

Our model did predict that

- the Moon would get darker; it did get dimmer, but not as dark as we thought.
- the shadow/darkness would move from one side of the Moon to the other during the eclipse (before and after totality).
- the eclipse would only happen during a full Moon.

Our model did not predict that:

- the Moon would look reddish (instead of dark) during the eclipse!

Use prompts such as the following to guide students to share their ideas (or their partner's ideas).

*** Supporting Students in Engaging in Developing and Using Models**

The Nature of Science idea that "scientific explanations are subject to revision and improvement in light of new evidence" applies here to our models. Students may need reassurance that it is okay to make principled changes to a model when we find something a model cannot predict or explain. It is also okay that we may not yet be able to explain what changes to make without further investigations.

Suggested prompts	Sample student responses
What did you and your partner notice when you compared your predictions to the images of the lunar eclipse?	*The Moon turns reddish/orange during a lunar eclipse!*
Wait, the Moon turned red? Let's make sure we're all understanding this. According to our model of the Earth-Sun-Moon system, what's happening during a lunar eclipse?	*Earth is lined up between the Sun and the Moon, so the Earth is casting its shadow on the Moon.*
So, what parts of this phenomenon did our model predict and explain?	*The Moon did get dimmer, but not as dark as we thought it would.* *The darkness/shadow did move from one side of the Moon to the other, like we predicted.* *We said a lunar eclipse would only happen during a full Moon and that was correct.*
What parts of a lunar eclipse did our model not predict or explain?	*The Moon didn't get completely dark like we thought.* *Our model did not predict that the Moon would turn red!* *Our model showed how the Sun, Moon, and Earth would need to line up to make a lunar eclipse happen ... but how would that make the Moon reddish?*

Additional Guidance

Connections to Me and My Community: Invite students to share cultural connections and stories they and their families have about lunar eclipses.

Also, encourage students to plan to watch a lunar eclipse in real life if possible. The website provides information about upcoming eclipses and where they will be visible in the world. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lead an Initial Ideas Discussion about possible causes for the model discrepancies. Display **slide X.** Say something like, *But I thought if there was no light reaching the Moon then the shadow would make it appear completely dark. What parts of our model do you think we would need to revise to explain that we still see it and it is that reddish color?* What do you think could be causing that to happen?*

Key Ideas

Purpose of this discussion: Gather possible causes for the dim, reddish Moon during an eclipse (rather than the fully darkened, not visible Moon our model predicted) and realize that we have questions to investigate about why this phenomenon happens.

Listen for these ideas: Accept all responses and expect controversy around them. As questions arise, encourage students to jot them down during this discussion; they will post them in part 5 of this lesson.

It is completely acceptable if students do not have ideas for possible causes yet, and they can sit with that curiosity and reconsider their thinking after listing related phenomena in the next part of the lesson. However, if students are stumped to the point of frustration, you could ask, *Where must that light illuminating the Moon be coming from?* (Students will likely answer the Sun, even if they are confused about the color.) You could then say, *It seems really strange that light could still be reaching the Moon. I wonder how that is happening*. You can then prompt them to consider any other experiences they've had where light has changed color—*What caused that color change?*

Sample student ideas might (but do not have to) include:

- The light is shining through something (what, though?) before it gets to the Moon.
- The reddish color of the Moon is somehow related to the reddish or orange color we sometimes see at sunsets.

4. Share related phenomena. 5 MIN

Materials: chart paper and markers

Turn and Talk about related phenomena. Display **slide Y.** Say something like, *It's interesting that the Moon turns reddish during an eclipse. But we're not entirely sure why yet … so, let's try to figure this out. When we're trying to explain something unexpected, it can be useful to consider other related phenomena. Let's think of other times where you have seen or heard about the Moon or the Sun or something else in the sky becoming dimmer or changing colors. When or where does that happen? Turn and talk with a neighbor about your ideas.*

Share ideas with the class. Create a new poster titled, "What causes a change in color for the Sun, Moon, or other things in the sky?" Ideally, this poster will be located next to or near the DQB since we will use it to drive our work in this lesson set of the unit. We will refer to this poster as the "Color Changes" poster for short.

Say something like, *We can use this poster to track our progress on figuring out these color changes. Let's start by collecting our related phenomena ideas here.*

Ask students to share their examples of related phenomena, and list them on the poster.

Sample student responses:

- *Sunrise*
- *Sunset*
- *Blood Moon*
- *Harvest Moon*
- *Blue Moon*
- *Sky turns dark and/or greenish when a big storm is approaching.*
- *Here at my home around Chicago, the sky usually looks pale blue, but when I travel to Arizona, the sky usually looks really deep blue out there.*
- *A green flash at the horizon at sunset*

5. Revisit our DQB to take stock of color questions. 8 MIN

Materials: sticky notes or index cards, Color Changes poster (created in part 4), Driving Question Board

Gather new questions. Display **slide Z.** Distribute sticky notes. Encourage students to write out any new questions they have from observing the lunar eclipse photos, evaluating our eclipse model, and brainstorming related phenomena. Say, *I overheard several questions and wonderings while we've been talking today, and I'm sure there are more. Take a minute to jot down any new questions you might have on a new sticky note—one question per sticky note.*

Have students add their new questions to the Color Changes poster you started in the previous step.*

Additional Guidance

At this point, accept whatever questions students have about colors in the sky or in space. The navigation between Lessons 12 and 13 will provide an opportunity to clarify that our atmospheric model of color change may not answer all of these questions and is, in fact, much of the reason we use technology that gets us beyond Earth's atmosphere in order to better observe objects in space.

Revisit the Driving Question Board for more color-related questions. Re-orient students to the DQB. Ask, *What other questions did we have that were related to color changes in the sky?*

As students identify previously posted questions about color, move those sticky notes to the Color Changes poster.

Record possible causes for these color changes. Have students briefly remind the class of the possible causes they identified earlier for the lunar eclipse color and other ideas they have about possible causes for their related phenomena. List these ideas on the Color Changes poster under the students' questions. Suggested prompts:

- *What ideas did you have about what might cause the Moon to turn red during a lunar eclipse?*
- *Why did you think the Moon didn't go completely dark during the eclipse?*
- *What might cause the sky to turn colors during a sunrise or sunset?*

Accept all responses.

When you have listed some potential causes, say, *It seems like we have a lot of good ideas about what might be happening. Let's think about some potential investigations we could do or data we might need to test our ideas and revise our model to explain color changes like this.*

Additional Guidance

At this point in the lesson, your students will have been in the Scientists Circle for an extended period of time. As such, we suggest that you give your students a movement break now. You might have the class transition back to individual desks or tables for the upcoming final part of the lesson (which could facilitate a mental shift from building understandings to planning investigations) and/or use inside-outside circles during partner talk as described in the next section.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**
The questions students generate here will help them refine their model and clarify their explanation of lunar eclipses. Also, their questions about related phenomena will help them extend their model and explanation to other situations. If time allows, have students use the same routine of sharing questions one at a time and grouping them with similar ones like when you create a unit's Driving Question Board.

6. Plan next steps.

9 MIN

Materials: science notebook, optional *Home Learning: Sunset Brightness and Color Data Collection* or optional *Home Learning: Choice Brightness / Color Data Collection*

Turn and talk to generate ideas for investigation. Display **slide AA.** Give students a moment to think to themselves and then have them turn and talk with a partner in response to these questions. Encourage students to look back through their science notebooks if that would be helpful.

- *What sort of tools have we used previously to try to explain Earth-Sun-Moon patterns?*
- *How could reusing those tools help us make progress on understanding these color-related phenomena?*
- *What are some new tools or sources of data that you think would be useful for investigating this type of phenomena?*

Alternate Activity

Consider using inside-outside circles to form changing partnerships so they can have a movement break while they discuss the questions on **slide AA**. Have the class stand up in front of their chairs, and have alternating students stay in front of their chair (forming the outside circle) and step into the circle (forming the inside circle) and turn around to face a partner in the outside circle. Have these partners discuss question 1. After a minute of talk time, say "rotate!" and direct either the inside or outside circle (or both) to take a step to their right and talk with that new partner about question 2. After another minute, rotate students once more so they have a new partner for question 3.

Share ideas for investigation. Ask students to share how we could investigate some of the color changes we have listed on our poster. Probe and prompt for other students with similar thoughts and highlight common ideas using prompts such as these:

- *Who else was thinking we could use _____?*
- *Why do you think that tool will be helpful?*
- *Did anyone have a similar idea?*
- *How would you use _____ to investigate that?*
- *I don't understand. Can someone else explain to me what ____ said?*

Sample student responses:

- *Use flashlights and spheres again (like in the first lesson set).*
- *Use simulations (like Stellarium or the Moon phases ones).*
- *Analyze photos of these objects and when these color changes occur.*
- *Shine lights on or through various things to look for color change.*

Close the discussion by saying something like, *I am looking forward to digging into some of these ideas next time we're together!*

(Optional) Assign home learning to collect local data. Present **slide BB.** Say, *Today we looked at images from sources like NASA, which are awesome. But if we work together, we can gather our own images as data to help us make sense of*

these color and brightness changes. Smartphones or tablets come with cameras, and we can download light meter apps that measure light using a unit called lux. Let's build a data collection together from our town. Here's what I'm thinking:

1. *Use a phone (your own or ask to borrow one from a family member for this project) or a device from school to take pictures of the sky at different times of the day.*
2. *When you take the picture, also use a light meter app to measure the light and take a screenshot of that measurement to record what it was.*

Safety Precautions



Remind students that it is not safe to look directly at the Sun, so when they take pictures and light meter readings of the Sun, they should shield their eyes and/or look away from it.

Ask, *If we're working to collect images to use together, what do we need to do so our data are reliable? What should we keep constant so we can compare our data?* Sample student responses:

- *We should use the same light meter app.*
- *We should always stand in the same place each time we take a photo so we can compare within the set.*
- *We should always point the camera directly at the object (the Sun or the Moon).*
- *We shouldn't stand in the shade.*

Explain to the class how you have planned for them to collect their data. You may choose to use a digital version of *Home Learning: Sunset Brightness and Color Data Collection* (directing students to collect sunset data at specific times) or *Home Learning: Choice Brightness / Color Data Collection* (more open-ended). Or, if you've set up another location for your class to collect their data (such as a shared slide deck), you might distribute paper copies of either handout so students have the instructions.

Also plan for and announce when students will share and discuss these data in class (see additional guidance in this guide). For example, consider replacing some of all of the photos used in part 2 of Lesson 9 with student-provided photos of sunsets, and possibly sunrises, moonrises, and moonsets, if available.

If you choose to use *Home Learning: Sunset Brightness and Color Data Collection*, sample data is provided for your reference in *Examples of Sun Brightness Data*.

Home Learning Opportunity



This home learning data collection task is optional. Collecting these data can enrich your students' experiences in this unit, but having this local data set is not critical to moving forward in the unit. Do not expect all of your students to complete it, and do not score or grade it for compliance. Students have a variety of resources (time and tools) outside of school and may or may not be able to participate in this activity.

Additional Guidance

Depending on their interest, your students may come up with additional ideas they want to investigate regarding brightness in the sky. Some possibilities include the following:

- Take measurements at sunrise instead of sunset.
- Investigate "twilight." What does it actually mean, and how bright is the sky during twilight?
- Is the Moon actually brighter during a "supermoon?"
- How much light is generated by stars? On a new Moon night, how much light (dark) do we have?
- Does the full Moon shine twice as brightly as a quarter Moon?
- Some people say our skies are never truly dark anymore. How could we use this light meter app to investigate light pollution in our area (and compare that to other areas)?
- Multiple light sources can create multiple shadows. Investigate the amount of light in shadows of different shades.
- How does the amount of light change throughout a day?
- How do seasonal patterns affect the amount of light during the day? Are some seasons "brighter" than others?

ADDITIONAL LESSON 8 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.SL.8.1.C Pose questions that connect the ideas of several speakers and respond to others' questions and comments with relevant evidence, observations, and ideas.

Students engage in speaking and listening with partners while they analyze images of lunar eclipses, compare those observations to what they predicted they would see, and suggest ideas for investigation. Students discuss ideas with the whole class when they share their ideas about potential model revisions, list related phenomena, consider possible causes, and collect their questions about color changes. In all of these situations, students should pose questions that connect their ideas to a partner's ideas and/or to ideas shared by their classmates, as well as reference evidence from their models and observations from the lunar eclipse images. That said, the goal of this lesson is to generate questions rather than figure out specific answers to them—that work will continue through this lesson set.

LESSON 9

Why do the Moon and Sun appear to change color near the horizon?

Previous Lesson

We analyzed images of lunar eclipses and compared them to our classroom lunar eclipse predictive model. The reddish color of the Moon that we observed during a lunar eclipse was unexpected. So, we listed possible causes of that reddish color and gathered examples of related phenomena of objects in the sky changing color. After posting our color-related questions, we generated ideas for investigating them.

This Lesson

Investigation

1 DAY



NASA

We examine images of the Sun and Moon at different times of day and propose that something about the Earth's atmosphere could be contributing to the color changes we see. After examining diagrams of the atmosphere, we observe images of the Sun from the ISS (which orbits Earth above the atmosphere). We add the Earth's atmosphere to our previous model of the Earth–Sun system and zoom in on two different views of the Sun at two different times of day. We predict that the different angles of light and/or the amount of the atmosphere the light travels through affect the difference in color we notice at sunrise compared to midday.

Next Lesson

We will investigate the color and brightness changes we see as light travels through the Earth's atmosphere by using a flashlight to simulate the Sun and a rectangular bin of milky water to simulate the atmosphere. We will use our investigation results to co-construct a model of light transmitting and scattering through the simulated atmosphere.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

9.A Revise our Earth–Sun system model to include ideas about how the Earth's atmosphere causes light from the Sun and Moon to change colors.

What Students Will Figure Out

- The color (and brightness) of the Moon and Sun seem to change when those objects are seen near the horizon.
- Sunlight in space (above the Earth's atmosphere) is whiter (and brighter) than sunlight we see from the surface of Earth through the atmosphere.

- Light travels through empty space (even when there is very little or no matter).
- Earth's atmosphere forms a layer (about 60 miles thick) of gas, water droplets, ice crystals, and dust particles that gets less dense higher up. That composition can change slightly in different places and from day to day.
- The atmosphere looks bluish during the day and from space.
- At sunrise and sunset, the light coming from the Sun passes through the atmosphere at a shallow angle compared to other times of day; when this happens, the light from the Sun takes a longer path to get to you, which means it travels through more of the atmosphere.
- Sunlight dims slightly in brightness and appears yellower, oranger, and then redder the more of Earth's atmosphere it passes through.

Lesson 9 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** Revisit ideas from Lesson 8 about when color changes happen in the sky.	A	Color Changes poster (from Lesson 8)
2	6 min	**OBSERVE SUNRISE, SUNSET, MOONRISE, AND MOONSET PHOTOS** Individually observe photos of sunrises, sunsets, moonrises, and moonsets and record noticings and wonderings.	B-E	
3	8 min	**DISCUSS WHETHER SUNRISES/SETS AND MOONRISES/SETS LOOK THE SAME EVERYWHERE** Discuss with partners and then in a whole group about whether sunrises, sunsets, moonrises, and moonsets look the same to all people everywhere.	F-G	
4	12 min	**ANALYZE A DIAGRAM AND IMAGES OF THE ATMOSPHERE** Use two diagrams of Earth's atmosphere to motivate observing images and video of the Sun and a sunrise as seen from outside of the atmosphere (from the International Space Station).	H-N	*Earth's Atmosphere Diagrams*, *Sunset from the ISS*
5	8 min	**CO-CONSTRUCT A MODEL OF HOW SUNLIGHT ENTERS EARTH'S ATMOSPHERE** Annotate a version of the Earth–Sun system model to include the atmosphere and the view of a person observing the atmosphere and sunlight at sunrise and noon.	O	*Comparing Sunlight at Sunrise vs. Midday*, tape, classroom consensus models of the Earth–Sun–Moon system
6	8 min	**PREDICT POSSIBLE CAUSES FOR COLOR CHANGE AS LIGHT COMES THROUGH THE ATMOSPHERE** Zoom in on parts of our model to identify differences in the angle of light, amount of atmosphere, and view of observing the Sun at sunrise and noon.	P-R	*Comparing Sunlight at Sunrise vs. Midday*, ruler and/or protractor (optional), Color Changes poster (from Lesson 8)

End of day 1

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • *Comparing Sunlight at Sunrise vs. Midday* • tape • ruler and/or protractor (optional)		• Color Changes poster (from Lesson 8) • *Earth's Atmosphere Diagrams* • *Sunset from the ISS* • classroom consensus models of the Earth–Sun–Moon system

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Online Resources 

Test the Sunset from the ISS video at 8.4 Lesson 9 Sunset from the ISS (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). There is no sound, but be sure the picture is clear and bright so students will be able to notice the color change of the Sun and the blue of the atmosphere.

You will want to be able to annotate on the model the class co-constructs of Earth's atmosphere, and possibly on the diagrams of the atmosphere as well. So, plan for whether you can annotate over those images on the slides as you present them or whether you will use digital or print copies to project or display while you make annotations.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students revisit ideas they figured out about Earth's atmosphere from the *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, such as the following:

- The atmosphere surrounds Earth's entire surface.
- The atmosphere is made of gasses (including water vapor), water droplets, ice crystals, and dust particles.
- Water vapor sticks to small, solid particles called cloud condensation nuclei (CCN) to form clouds.
- What exactly is in the atmosphere (how much water vapor, how many CCNs, etc.) can change from place to place and day to day.

If your students did not participate in *Storms Unit*, plan to take a few moments to develop these ideas while you are examining the images and diagrams in this lesson.

You will notice that the atmosphere diagrams used in this lesson have scales in metric and customary units. We anticipate that most students in the United States will be better able to make sense of the distances involved in these diagrams in feet and miles because they are more familiar; students likely have a frame of reference for these distances from everyday use.

In this lesson, students begin to work with ideas that they will continue to investigate in the rest of this lesson set. Here is a summary for your information. When sunlight reaches Earth, several things occur. Some of the light is reflected back into space by our atmosphere and some passes into our atmosphere where gases and other particles change its color and brightness. The angle of the light, the thickness of the atmosphere, and the composition of particles in the atmosphere each play a role in what the color and brightness of this light we see from the surface of Earth looks like. Blue wavelengths of light scatter in Earth's atmosphere, giving a bluish tint to the sky. If light travels through more atmosphere, like it does at sunrise and sunset, that light will appear more orange/red when it reaches our eyes (or reflects off the edges of a cloud closer to us) because much of the blue wavelengths of light were scattered before that light reached us. If the sunlight travels through less atmosphere, it appears more white because fewer wavelengths are scattered. At this time, these ideas are for your background knowledge—students will figure them out in Lessons 10, 11, and 12.

Where We Are NOT Going

In this lesson when we refer to how the Moon changes at the horizon, we're not referring to the phase or shape of the Moon, which students figured out in earlier lessons. Rather we're referring only to the color and/or brightness changes of the Moon.

The atmosphere diagrams used in this lesson do not name the layers of the atmosphere nor types of clouds because that information is not critical to the work students do in this unit and, in fact, could distract them from the figuring out they're doing here. If you think your students are especially curious about ancillary details like these, you might suggest they use time outside of class to do further independent research.

Throughout this lesson set, we are not describing differences between the wave and particle models of light nor why light scatters, refracts, reflects, or interacts with different particles differently.

LEARNING PLAN FOR LESSON 9

1. Navigation

3 MIN

Materials: Color Changes poster (from Lesson 8)

Recall the phenomena we started thinking about last time. Display **slide A** and refer to the Color Changes poster you created in Lesson 8 asking, "What causes a change in color for the Sun, Moon, or other things in the sky?"

Say, *Last time we realized our model couldn't explain the red Moon during a lunar eclipse, which got us thinking about other times we've seen or heard about the Sun, Moon, or other things in the sky becoming dimmer and/or changing colors. What other phenomena might be related to color change like we observed in the lunar eclipse?*

Accept all responses and use prompts such as the following to build connections between students' experiences and expand on their ideas:

- *Has anyone else seen a memorable _____(sunrise, sunset, full Moon, etc.)?*
- *Were you with anyone else at the time? What did they think? Were there additional ideas or memories they brought up?*
- *What else do we see like that in the sky?*
- *What other connections can you make?*
- *What are other times of the day/night/year when we think about colors in the sky?*

If needed, add any new ideas to the other related phenomena listed on your Color Changes poster.

Transition into today's work. Ask, *How could investigating these phenomena also help us make progress on figuring out what might be happening in a lunar eclipse?*

Sample student response:

- *These phenomena all involve changes in the color we see, so if we figure out what is causing color change in one, it may explain what is causing the color change in many or all of them.*

2. Observe sunrise, sunset, moonrise, and moonset photos.

6 MIN

Materials: science notebook

Introduce a Stop and Jot activity for observing photos. Display **slide B.** Explain that you have photos of some of these related phenomena for us to observe. Direct students to find the next clean page in their science notebooks for jotting down what they notice and wonder as they examine the photos.

Individually examine moonrise and sunset photos. Present **slides C, D, and E**, providing about 2 minutes per slide so students can record in their notebooks what they notice and wonder about these images.

3. Discuss whether sunrises/sets and moonrises/sets look the same everywhere. 8 MIN

Materials: None

Consider whether sunrises/sets and moonrises/sets look the same everywhere. Display **slide F.** Ask students to turn and talk with a partner about this question: *Would the brightness and color of the Sun look the same at sunset for that same day everywhere on Earth? Or would the brightness and color of the Moon look the same at moonrise that same day everywhere on Earth? Why do you think it would be the same or not?*

If it's helpful, flip back to the images on **slides C, D, and/or E** and clarify, *Would people everywhere in the world see it just like this? Why or why not?*

After a moment of partner talk, use prompts such as the following to have students share their ideas with the whole group.

Suggested prompts	Sample student responses
Would the brightness and color of the sunset or moonrise that day look the same for people everywhere on Earth? Why?	*No, the sunset/moonrise will not look the same everywhere.* *It would look different in different places.*
If needed, use specific examples such as the following: • *Would the sunset look the same from the top of a really tall mountain?* • *What about in a desert?* • *I heard that Forks, WA is the rainiest, cloudiest place on Earth—would it look the same from there?* • *How about from the middle of the ocean?*	*The weather wouldn't be the same everywhere. It might be cloudier or clearer in different places that day.* *I've heard that sunsets are especially colorful when there are dust storms or wildfires around.* *Around big cities there might be more pollution in the air and that could change how things in the sky look.*
I hear you saying that there might be different things in the air or the atmosphere in those different places that could be affecting what people are seeing in the sky. What are some things in the atmosphere that could be different from one place on Earth to another?	*clouds* *dust* *smoke or other kinds of pollution* *gasses like water vapor—humidity is different in different places*

Additional Guidance

Students may mention the ozone layer during today's discussion of the atmosphere. Since this is not a central concept to the development of the effect of the atmosphere on light from the Sun (or Moon), you don't need to dwell on the specific characteristics of ozone or that layer. It's enough to acknowledge that within any of the layers of the atmosphere we find the gasses, clouds, and particles (that might affect light).

Problematize the role of the atmosphere. Display **slide G.** Say, *It seems like quite a few of our ideas for why sunrises, moonrises, sunsets, and moonsets might not look the same are related to stuff in the atmosphere like clouds, dust, and*

gasses. What if we could watch a sunrise from outside Earth's atmosphere? What do you think the light from the Sun would look like if there was no atmosphere between us and the Sun? Turn and talk with a neighbor about that. Allow students a minute to talk with a partner, then move on to the next step (it is not necessary to share ideas aloud now, as you will bring them into the class discussion in the following part of the lesson).

4. Analyze a diagram and images of the atmosphere.

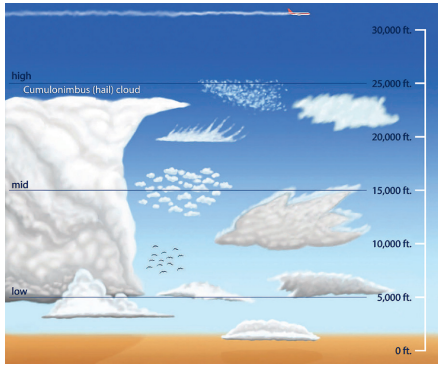
12 MIN

Materials: science notebook, *Earth's Atmosphere Diagrams*, *Sunset from the ISS*

Additional Guidance

If your students did not participate in *Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit)*, rather than asking what students remember about the atmosphere, take a few moments to examine the images on **slide H** together as a class. Have students point out what they notice about the atmosphere.

Recall what we know about Earth's atmosphere from the *Storms Unit*. Say, *We might not have thought much about what's in our atmosphere recently, maybe not since the Storms Unit. What were some things we figured out about Earth's atmosphere from our work in the Storms Unit? Let's look back at some of the data and diagrams we explored in that unit to help reorient ourselves to some of what we figured out.* Display **slide H.** This image and the others used in this lesson are also available in *Earth's Atmosphere Diagrams*.



Sample student responses:

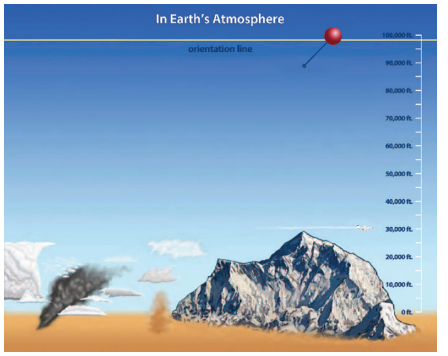
- *The atmosphere surrounds Earth's entire surface.*
- *The atmosphere is made of gasses (including water vapor), water droplets, ice crystals, and dust particles.*
- *Water vapor sticks to small, solid particles called cloud condensation nuclei to form clouds.*
- *What exactly is in the atmosphere (how much water vapor, CCNs, etc) can change from place to place and day to day.*
- *Clouds tend to form in the first 30,000 feet of the atmosphere.*
- *It gets colder the further you go up.*

Ask, *Can we see the atmosphere from here on Earth's surface? Can we see it all the time?* Sample student responses:

- *Yes, it's the sky!*
- *Yes, looks blue! (But sometimes clouds or smog make it look white or grayish.)*
- *We can see clouds that are in the atmosphere.*
- *It's harder to notice the atmosphere at night - we can see stars and the Moon through it, though.*

Say, *This diagram was one we used to figure out what was going on in the part of the atmosphere where we see clouds form. But many of the gases that make up our atmosphere can still be found above the height of the tallest clouds. Let's look at a diagram at a bit larger scale to figure out a little more about the atmosphere higher up than what's shown in this diagram.*

Additional Guidance

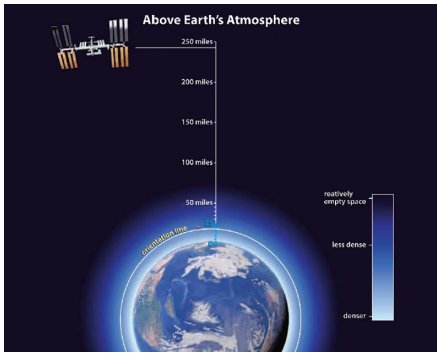


You may find it helpful to annotate the atmosphere diagrams while your class discusses them. If annotating on slides is not an option with your technology, we have provided *Earth's Atmosphere Diagrams*, which you can use as a print or digital version.

Examine a diagram of the atmosphere from a near-Earth perspective. Display **slide I** and use prompts such as the following to help orient the class to the heights of objects in the nearer Earth atmosphere.

Suggested prompts	Sample student responses
What do you notice about where natural things are in the atmosphere? Where do you see the things we mentioned?	*The clouds and dust and smoke all seem pretty close to Earth—similar heights to mountains.* *Some clouds are even lower than Mt. Everest, but some are higher.* *None of the clouds go higher than about 45,000 feet.*
Does the atmosphere have the same things in it everywhere all the time?	*No, the weather and clouds can change on different days and in different places.* *No, there might be more dust or pollution in some places depending on what's happening on the ground below the atmosphere.* *And the wind can move things around.* *I wonder if maybe it changes with different seasons, too, like how humid it is.*
What about artificial things that people have made; where in the atmosphere are they found?	*The plane is pretty high—almost as high as the tallest clouds.* *The weather balloon is higher! They can go up to 100,000 feet!*
What do you think we would find if we went higher still? What do you think is above the things we're viewing in this diagram?	*Answers will vary but may include ideas such as:* • *more air* • *thinner air* • *satellites* • *International Space Station* • *space junk* • *moon* • *planets* • *stars*

Examine a diagram of the atmosphere from a global perspective. Display **slide J.** Say, *The first atmosphere diagrams we examined were closer to Earth. This one is like we're looking at Earth and its atmosphere from space. The amounts and types of specific gases or other particles in the atmosphere change somewhat as we go higher up, but in general, the atmosphere gets less and less dense the higher up you go. Eventually, it's so thin, at about 60 miles above Earth's surface, that you can't fly airplanes or float balloons in it anymore. Above that point is considered being in space.*



Use prompts such as the following to help orient the class to the height of other objects people have launched into space.

Suggested prompts	Sample student responses
What about artificial things that people made and launched into space? What example of these do you see in this diagram, and how high is it compared to where the atmosphere is located?	*The ISS is about 250 miles above Earth! It's in space!*
The International Space Station has cameras on it that can make observations of Earth and other things in space too, like the Sun. If we look at sunrise, sunset, or just the Sun from the ISS, would it look the same as it does here on Earth? different? Why do you think so?	*Not the same—no clouds, plane trails, dust, etc. to get in the way of the light.* *Not the same—no atmosphere (or very little) in the way.* *It might be the same; it's still just sunlight.* *We're not sure; have the ISS astronauts ever taken pictures or videos?*

Compare side-by-side Sun images. Display **slide K,** which shows two photos of the Sun: one taken from Earth and one from space (by scientists on the ISS). Say, *The scientists living on the ISS have taken pictures of the Sun and shot video of many sunrises and sunsets as they see them from above Earth's atmosphere.*

Ask students to briefly turn and talk with a neighbor about what they notice about the Sun/sunlight in these two photos, then have them share with the whole class.

Sample student responses:

- *The Sun looks whiter from space and yellower from Earth.*
- *The Sun looks brighter in space than it does on Earth.*
- *There isn't any color in the space view; the Sun is just white.*

Probe deeper about how light from the Sun travels. Display **slide L** and discuss using prompts such as these.

Suggested prompt	Sample student response
How does the image of the phone in the vacuum jar provide evidence that light can travel through empty space?	*We can see the phone (and the bottom of the jar, etc.), so light must be traveling from there to our eyes even though there's empty space inside the jar.*

Suggested prompts	Sample student responses
Is light from the Sun able to travel through empty space (before it gets to the Earth's atmosphere)?	*yes*
Light doesn't need matter to travel through, like sound does?	*no*
How do you know?	*Since we can see the light when it gets to us from the Sun—like in both of those views of the Sun we can see it, even though it's in space—the light must be getting to us.*

Watch an ISS sunset video. Display **slide M.** Direct students to find the next clean page in their science notebooks to record their observations while they view a video of the sunset as seen from the ISS. Play the video linked here 8.4 Lesson 9 Sunset from the ISS (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Then play the same video a second time so students can turn and talk with a partner about their ideas while it's playing. Display **slide N**, so students can refer to the series of still images from the video as they continue to talk. This image set is also available in *Sunset from the ISS*.

Additional Guidance

Point out to students that this is a sped-up view of Earth, captured by the Expedition 59 astronauts onboard the International Space Station. Explain that the station is traveling at a speed of close to 5 miles per second and that it orbits the Earth every 90 minutes, so the station residents actually see 16 sunsets each "day" (every 24 hours).

Share what we noticed about the ISS sunset. Keep **slide N** displayed so students can reference the series of still images from the video. Ask students to share what they observe(d).

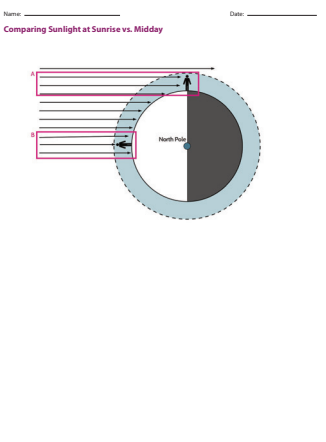
Sample student responses:

- *The Sun looks so bright when it's above Earth's atmosphere.*
- *The Sun's light is so white—not yellow or orange or any color—when it's above Earth's atmosphere.*
- *I can see the atmosphere like a glowing blue arc over the Earth; when the Sun gets to a certain position, it lights up the atmosphere.*
- *The Sun starts to look yellowish and then more orange as it gets closer to setting; it looks like it's right in line with the blue atmosphere arc as its color is changing.*
- *The Sun gets much, much dimmer as it sets.*
- *The Sun looks red right before it disappears.*

5. Co-construct a model of how sunlight enters Earth's atmosphere.

8 MIN

Materials: *Comparing Sunlight at Sunrise vs. Midday*, tape, science notebook, classroom consensus models of the Earth–Sun–Moon system



Work together as a class to develop a model of the Sun–Earth system that includes Earth's atmosphere.* Display **slide O**. Refer to the classroom consensus models of the Earth–Sun–Moon system. Say, *Let's use all of these new findings to inform a revision to our model of how we see things in the sky. Our Earth–Sun–Moon system model already helps us understand day/night cycles, Moon phases, and the movement of stars and planets around the Earth. But now we're talking about specific moments in time, like sunrise or sunset, so let's dig deeper into our model to help us fully understand what we see at those times and what is different about parts in the system and how they interact at those points in time. Since we already created some of this model together, I have a copy of the model for us to start with today.*

Distribute *Comparing Sunlight at Sunrise vs. Midday*, direct the class to add it to their science notebooks, and direct the class to the first model on the handout. Prompt the class to label the components of the model listed here and annotate the model together, as shown in the example below and on *Teacher-Annotated Version of Comparing Sunlight at Sunrise vs. Midday*.

- Day (white side) and night (black side)
- Rotation of the Earth (draw a curved arrow to indicate this)
- Sunlight
- Atmosphere (Note that this was missing from our previous models.)

Use prompts such as the following to consider the people in the model and their views. If it is helpful to the sunrise/sunset conversation, you may want to add a person at a new point "C" directly opposite Person A.

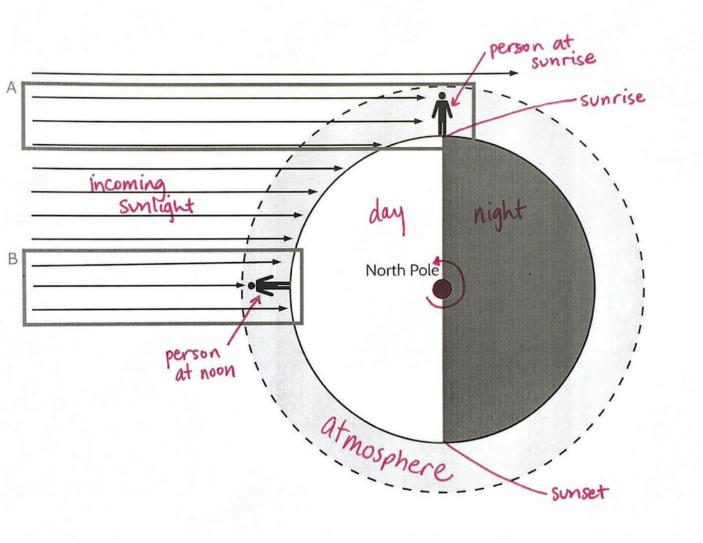
Suggested prompts	Sample student responses
Let's consider what perspective we are viewing Earth from in this model before we consider what the small people in the model represent. Based on the label of the dot in the center, how would you describe the perspective we have looking at this model right now?	*We are viewing the Earth from above the North Pole, looking down on the Northern Hemisphere.*
What time of day is it for Person A?	*sunrise*
Imagine that person pointing to the Sun. Where would they say the Sun is in the sky?	*near the horizon*

*** Supporting Students in Engaging in Obtaining, Evaluating, and Communicating Information**

In order to develop and use this model, students integrate the qualitative scientific information they gathered from the still photos and video of sunrises/sets and moonrises/sets they saw earlier with their prior knowledge and the diagrams of the atmosphere, which also includes quantitative information about the relatively thin layer of gases that encircles the Earth. As they work to propose how Earth's atmosphere could cause the color changes we see in the Sun and Moon at the horizon, refer back to the images and diagrams as needed to support their sensemaking.

Suggested prompts	Sample student responses
What do you expect the Sun and sky to look like for Person A?	*The Sun is at the horizon and probably looks dim and reddish/orange/yellow.* *The clouds (if there are any at that time) might be a variety of colors: pink, orange, purple, etc.*
What time of day is it for Person B?	*noon (midday)*
Imagine this person pointing to the Sun. Where would they say it is in the sky? How would the Sun's elevation compare to where it was for Person A?	*The Sun is higher up in the sky.*
What do you expect the Sun and sky to look like for Person B, at midday?	*Person B would see white clouds (if there are any that day) and the sky will be blue.* *The Sun will be bright in the sky (if the clouds aren't covering it).*

Label the times of day for Persons A and B on your model. Say, *Let's zoom in on these people and their perspectives to think more about what they might be seeing in the sky and why.*

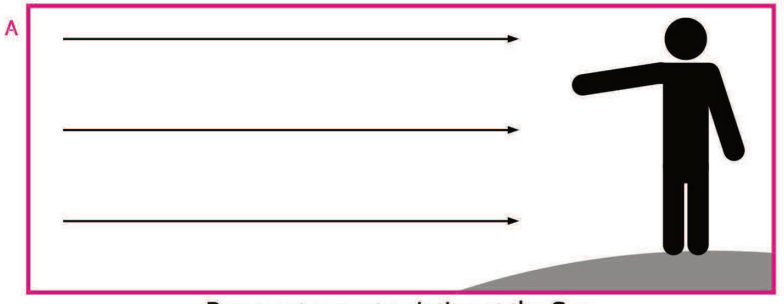


6. Predict possible causes for color change as light comes through the atmosphere.

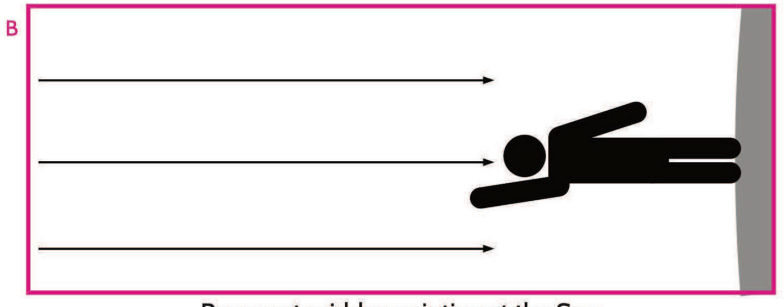
8 MIN

Materials: *Comparing Sunlight at Sunrise vs. Midday*, ruler and/or protractor (optional), science notebook, Color Changes poster (from Lesson 8)

Introduce the zoom-ins on our new atmosphere model.* Display **slide P** and refer students to the second model on the handout in their notebooks. Say, *In the past we have used zoom-in models to look at something really small. This is another situation where we can use similar thinking about what is happening at a different scale. Let's also think about what is different about the parts of the system that we are interested in at this zoomed-in scale. This zoom-in doesn't focus on particles, which we have included in the past to explain some phenomena. Instead we are zooming in on a smaller part of the Earth within the larger Earth–Sun system. Let's make sure we know what everything is.*



Person at sunset pointing at the Sun



Person at midday pointing at the Sun

Use prompts such as the following to orient students to these zoom-ins on the model.

Suggested prompt	Sample student response
What do the arrows coming in from the left represent?	*sunlight*

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**

Throughout this unit we have been increasing the complexity of our model of the Earth–Sun–Moon system by taking different perspectives and refining our understanding of the relationships between these components. The perspective we're taking now, where we zoom in on a smaller "slice" of Earth's atmosphere to consider how light interacts with it, is a completely new perspective in the unit. Relative to the planetary scale we've been using thus far, this zoom-in helps us consider the Earth–Sun system on a much smaller scale, but obviously not nearly the scale of previous zoom-ins that help us explain interactions at the cellular or molecular level.

Suggested prompts	Sample student responses
What is that layer the person is standing on?	*the ground*
What does the dotted line represent?	*the atmosphere*
What direction does Person A need to look in to see the Sun?	*straight ahead toward the horizon*
What direction does Person B need to look in to see the Sun?	*straight up (overhead)*

Talk with a partner about what might be causing the change in color we've noticed. Display **slide Q**. After reorienting to the zoom-ins. Prompt the students to talk with a partner about the questions on the slide:



- What similarities and differences are there between what Person A and Person B are experiencing?
- Why might the sky look different to each of them?

Provide about 2 minutes for students to think and talk. You might encourage them to jot down some ideas in their notebooks to share with the whole class.

Assessment Opportunity

Building towards: 9.A Revise our Earth–Sun system model to include ideas about how the Earth's atmosphere causes light from the Sun and Moon to change colors.

What to look/listen for: As students talk with their partners and then again during the upcoming discussion, listen for students to share ideas such as these:

- Person A (seeing sunrise) is seeing a dimmer, reddish-orange-colored Sun because the light is passing through more of the atmosphere.
- Person B (midday) is seeing a brighter yellower/whitish Sun because the light is passing through less of the atmosphere.
- Materials in the atmosphere (such as water vapor, clouds of water droplets and ice, other gasses, dust, and pollution) are affecting the color of light from the Sun–the more atmosphere the light travels through (such as for Person A), the more effect (more color change) we see.
- Other differences in the atmosphere (more pollution in some places than others, for instance) could also affect how people see the Sun from their position.

What to do:

- If students need more support in determining the different "amounts of atmosphere" the sunlight travels through to reach Person A and Person B, encourage them to use a ruler and/or protractor to actually measure the lengths and/or angles of the sunlight approaching Person A and Person B to help them contrast those positions.
- Refer back to the images we used earlier in the lesson to clarify with students what each person would be seeing; you might even print out and attach small photos of the sky at sunrise near Person A and the Sun in the sky at noon near Person B to help students associate the view each person would have of the Sun and the different colors they might see.

- Take note of which students may need support during the sharing discussion that follows this partner talk; consider checking in with them before the whole-group sharing to alert them that you'll be asking their help measuring for the class, annotating the model, or restating what someone else said in their own words.

Discuss why we might see different colors in the sky at different times of day. Display **slide R**. Use prompts such as those shown here to have students share their ideas of possible causes for the color changes we've noticed.

Suggested prompts	Sample student responses	Follow-up questions
What variables did you or your partner identify that might be causing the differences we see in the sky between noon and sunset?	*maybe the angle of the incoming light*	*Why might that be important?* *Could we measure that?*
	if there's different stuff in the atmosphere	*What would cause there to be different stuff in the atmosphere?* *Do you mean at different times and/or different places?*
	how far the light travels through the atmosphere	*How did you notice that?* *Could we measure that?*

Additional Guidance

As students share their ideas, encourage them to show their thinking by pointing out what they mean on the models. Potential questions to support this idea sharing include:

- Can anyone restate what ___ just shared in your own words to be sure we understand?
- Did anyone else talk about that with their partner?
- I'm not sure what you mean by that. Please help us understand your thinking by showing us on the model.
- Does everyone agree with that point? Is there anyone who doesn't agree?

Navigate to next time's work. Add a "possible causes" section to your class Color Changes poster and list the possible causes that students mentioned.

Look ahead to the next class by saying something like, *We have some great ideas of possible variables that could be causing these changes in the color of light. Let's investigate those next time. I will bring in some supplies for us to use to simulate light passing through the atmosphere. We can investigate whether changing some of these variables you suggested will have any of the effects you're predicting.*

LESSON 10

How does light interact with matter in the atmosphere?

Previous Lesson

We examined images of the Sun and Moon at different times of day and proposed that Earth's atmosphere could contribute to the color changes we saw. After examining diagrams of the atmosphere, we observed images of the Sun through the atmosphere and from the ISS (above the atmosphere). We revised our model and predicted that the amount of atmosphere the light travels through affects the difference in color we see at sunrise compared to midday.

This Lesson

Investigation

1 DAY



We recall our ideas about what might cause the color and brightness changes we see as light travels through more or less of Earth's atmosphere, and we map those variables to materials we can use to investigate this: flashlights and rectangular bins of milky water. After predicting the light changes we expect to see, we carry out an investigation and record what we observe about the color and brightness of light passing through more and less of our simulated atmosphere. We discuss our observations with the class and co-construct a model of light scattering and transmitting through the simulated atmosphere.

Next Lesson

We will investigate times and perspectives needed for white light to split into rainbows. We will discover that different materials cause the colors of light to bend differently, causing a rainbow. We will investigate how recombining colors of light changes the color and brightness of light. When all colors combine, we get white light.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

10.A Carry out an investigation to collect data as evidence of the effect of light interacting with a simulated atmosphere.

What Students Will Figure Out

- Although sunlight is white in space, some of the colors are scattered out as it passes through Earth's atmosphere, so it appears yellower, oranger, and redder the more of Earth's atmosphere it passes through. Sunlight also dims a bit in brightness the more atmosphere (longer path) it passes through.
- When we shine a flashlight through a simulated atmosphere, the original white color becomes oranger or redder the more "atmosphere" it travels through.
- We observe a blue color when the white light interacts with the particles in the simulated atmosphere.
- When we shine a flashlight through a simulated atmosphere, the brightness of the light we see decreases the longer the path the light travels through it.

Lesson 10 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	8 min	**PREPARE TO INVESTIGATE LIGHT SHINING THROUGH THE ATMOSPHERE** Review students' ideas about variables that cause color changes in sunlight and introduce today's investigation materials.	A-B	Color Changes poster (updated with possible causes in Lesson 9)
2	12 min	**MAP INVESTIGATION ELEMENTS AND MAKE PREDICTIONS** Map the elements of the milky water lab setup to real-world components and predict the light changes we expect to see in each scenario of the lab.	C-E	*Investigation Elements Map, Predictions, and Results*, tape, Lesson 9 Atmosphere Zoom-ins on the Earth–Sun System Model
3	14 min	**CARRY OUT THE LIGHT AND MILKY WATER LAB** Make observations of light passing through a simulated atmosphere to observe color and brightness changes.	F-H	*Investigation Elements Map, Predictions, and Results*, *Instructions for the Light and Milky Water Lab*, Light and Milky Water Lab
4	13 min	**CO-CONSTRUCT MODELS TO EXPLAIN OUR INVESTIGATION RESULTS** Meet in a Scientists Circle and co-construct a model of light scattering and transmitting through the simulated atmosphere.	I-J	*Investigation Elements Map, Predictions, and Results*, sticky notes, Color Changes poster, chart paper, markers

End of day 1

Lesson 10 • Materials List

	per student	per group	per class
Light and Milky Water Lab materials	• safety goggles	• clear rectangular acrylic bin • water • small cup of powdered milk • flashlight • ¼ teaspoon measure • small block or book to prop up flashlight • white paper	
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Investigation Elements Map, Predictions, and Results* • science notebook • tape • *Instructions for the Light and Milky Water Lab*		• Color Changes poster (updated with possible causes in Lesson 9) • Lesson 9 Atmosphere Zoom-ins on the Earth–Sun System Model • sticky notes • Color Changes poster • chart paper • markers

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Be sure you have materials ready to add the following word to the Word Wall: **scatter**. Do not post this word on the wall until after your class has developed a shared understanding of its meaning during the discussion and co-construction of the model in part 4. You may also choose to post the words **reflect** and **transmit** at that time; students should recall those words from *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*.

Online Resources 

Light and Milky Water Lab

- **Group size:** approximately 3 students per group
- **Setup:**
  - Obtain clear rectangular bins for each group. When testing this lab, we used clear acrylic bins that were about 12 in long x 6 in wide x 3.5 in deep and held about 2 quarts of water when they were ¾ full. Unless the bins you use are much larger than this, you will not need to adjust the amount of milk powder students add to the water.
  - Check batteries and bulbs in the flashlights.

- Have water available at a sink and/or have ready about 2 quarts of water for each group (room temperature is fine). Tap/sink water is perfectly suitable for this lab, no special type of water is needed.
- For each group, measure at least 4 teaspoons (enough for ½ teaspoon each for 6 classes) of powdered milk into small paper cups. Non-fat powdered milk is okay.
- A video of this lab is available at 8.4 Lesson 10 Light and Milky Way Lab for your reference. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) Also, in case your student(s) are not able to complete this lab in the classroom, they can collect their data from that video. Additionally, sample investigation data are available in *Sample Investigation Images*.

- **Notes for during the lab:**
  - Modern LED flashlights tend to emit a bluer light than traditional incandescent bulbs, and the amount of blue tint to the light varies by flashlight. So, your classroom results may vary a bit from the provided images and video.
- **Safety:**
  - Print MSDS for Powdered Milk, post in the lab per school procedures.
  - Use indirectly vented chemical splash goggles and non-latex aprons during the setup, hands-on, and takedown segments of the activity.
  - Immediately pick up any liquid spilled on the floor in the work zone so it does not become a slip/fall hazard.
  - Use caution when working with water - keep clear of any electrical receptacles or electrical equipment to protect against shock hazards.
  - LED flashlights can produce intense light levels. Do not look directly into the light source to prevent eye injury.
  - Have students ask the teacher where to safely place equipment/materials upon completing the lab activity.
  - Have students wash their hands with soap and water immediately after completing this activity.
- **Disposal:** All waste water can be disposed of down the sink.
- **Storage:** Store milk powder in a cool, dry place according to package directions. For long-term storage, remove batteries from flashlights to store in a cool, dry place.

Lesson 10 • Where We Are Going and NOT Going

Where We Are Going

Students will see the effects of light scattering as it passes through a simulated atmosphere. Blue light will be scattered disproportionately to red light causing the light to appear orangish when viewed through the simulated atmosphere. When passing through a shorter amount of atmosphere, the light should appear brighter and less reddish orange than when passing through a longer amount of atmosphere. Students will co-construct a model at the end of this lesson that they will use to explain similar phenomena in Lessons 11 and 12.

When describing the amount of atmosphere light passing through in this lesson, we chose to use the phrases "longer/shorter amount" when discussing the distance the light travels. We used the phrases "greater/less density" or "more/fewer particles" when discussing how much particulate matter/powdered milk is in the atmosphere. You and your class can explicitly decide how you want to refer to these different ways of comparing the atmosphere situations light is passing through.

In this lesson, students access specific prior knowledge they bring in from the *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* that when light shines on an object, it can be reflected or transmitted. Students use this prior knowledge to consider what could be going on with light shining through Earth's atmosphere and the simulated atmosphere of milky water.

The word "scattered" is used in an optional extension at the end of the *One-way Mirror Unit* where students investigated how light "glares" off some highly polished surfaces, and they considered why we can see reflections in a calm, smooth lake and a newly waxed gym floor (but not a wind-choppy lake or a scuffed-up, sanded-down gym floor). Scattering is described in that unit like this: *When light shines on any surface, it always reflects off the surface in a V shape. If the surface of an object is very smooth at the microscopic scale, all the light reflects in the same direction. This is why you see a glare when light shines on highly polished materials. If the surface is rough, light reflects in all different directions. This type of reflection is called scattering.*

When we discuss scattering in this lesson, we also consider it a special case of reflection where the light is bouncing off in all different directions. Instead of a surface, the light is bouncing off molecules and other particles in the atmosphere (and our simulated milky water atmosphere), which scatters it in many different directions.

Where We Are NOT Going

In this lesson and lesson set, students are investigating the color changes we see in light due to the scattering and refraction of light by Earth's atmosphere. Do not confuse the reddening we investigate in this lesson set with the red shift of very distant objects in space. That red shift is caused by the "stretching" of wavelengths of electromagnetic radiation as the universe expands (making them longer, so the light is seen as shifting toward the red part of the spectrum). Students will have the opportunity to investigate red shift in high school as part of their work on HS-ESS1-1.

LEARNING PLAN FOR LESSON 10

1. Prepare to investigate light shining through the atmosphere.

8 MIN

Materials: Color Changes poster (updated with possible causes in Lesson 9)

Navigate into today's work. Display **slide A.** Briefly revisit the Color Changes poster and classroom consensus model you created in Lesson 9 showing the atmosphere as part of the Earth–Sun system. Ask students to summarize the ideas they had about why these variables might be a cause for color (and brightness) changes in sunlight at sunset (and sunrise).

Sample student responses include the following:

- *The angle of the sunlight shining on the Earth is different at those times of day.*
- *There's different stuff in the atmosphere in different places and at different times.*
- *The light is traveling through different amounts of the atmosphere/how far it travels through the atmosphere.*

Introduce today's investigation elements. Display **slide B**. Say, *I've found a way for us to simulate the structure of the atmosphere in our own classroom so we can carry out some investigations first hand. Let's think through how we can include something to represent*

- *the atmosphere (made of gasses and larger particles), and*
- *sunlight.*

Introduce a source of sunlight. Say, *Just like we've done before, we can use a flashlight to simulate the Sun.*

Turn the flashlight on and point it toward the students. Ask, *What do you notice about the color of the light coming from this flashlight?*

Sample student responses:

- *It's white.*
- *It's really bright.*

Safety Precautions

Some LED flashlights are very bright, even when viewed through milky water. Direct students not to look directly at the light for longer than a quick glance.



Introduce a way to simulate the composition of the atmosphere. Explain how each of the following will represent the corresponding part of the atmosphere:

- *Water can simulate the molecules of gasses in the atmosphere.*
- *A small amount of milk powder can simulate the relatively small particles that can be in the atmosphere, like water droplets and dust.*

Additional Guidance

One of the limitations of this simulated atmosphere is that water is not perfectly analogous to the gasses in the atmosphere. Students will have a hard time seeing any effect of the plain water on the light during this investigation; they will notice the scattering and transmission of different colors when they add milk powder. However, for your information, the molecules of gasses in Earth's atmosphere do scatter shorter-wavelength blue light without particulate matter involved (in fact, a "clearer" sky looks deeper blue). You may choose to acknowledge with students that, like other models, our simulated atmosphere has limitations, but do not dwell on these specifics; they will figure out that white light refracts into different colors in Lesson 11, but exploring specific wavelengths of light and/or how they interact with various sizes of molecules or particles specifically is beyond the scope of this gradeband.

Demonstrate mixing a small bit of milk powder into a clear bin of water.

Say, *Let's take a moment to record how these elements of our investigation map to the corresponding parts of the Earth–Sun system.*

2. Map investigation elements and make predictions.

12 MIN

Materials: *Investigation Elements Map, Predictions, and Results*, science notebook, tape, Lesson 9 Atmosphere Zoom-ins on the Earth–Sun System Model

Map investigation elements to the Earth–Sun system. Display **slide C.** Distribute *Investigation Elements Map, Predictions, and Results* and direct students to add it to their science notebooks.

Say, *Why are these materials good choices to represent their real world counterparts? For example, why does it make sense to use water instead of air? Or milk powder instead of dust? Take a few minutes to think this through how these materials relate to the real-world things we're trying to simulate.*

Direct students to work with a partner to complete the first table. Give students 5–6 minutes to work. Circulate to clarify any confusion while students work, referencing our Lesson 9 Atmosphere Zoom-ins on the Earth–Sun System Model as needed. Sample responses are shown in *Investigation Elements Map, Predictions, and Results*.


Name _____ Date _____

Investigation Elements Map, Predictions, and Results

Directions: Fill in the table as you map each part of the investigation set-up to the real-world phenomenon we are wondering about.

This part in our investigation...	is like this part in the real world...	because...
flashlight:	the sun	
water	the gasses of our atmosphere	
milk powder/	the particles in the atmosphere that are larger than molecules	
adding additional milk powder to the water	when the particles in the atmosphere where or when the particles are more dense	
the color of light from the flashlight before it reaches the liquid	the color of light from the Sun before it reaches Earth's atmosphere	
length of the container w/ liquid	the longer path of light through the atmosphere at sunrise or sunset	
width of the container of liquid	the shorter path of light through the atmosphere at noon	

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Orient students to the investigation scenarios. Display **side D**. Give students a moment to orient themselves to the drawings in the second table of *Investigation Elements Map, Predictions, and Results* and work with students to annotate the drawings and/or note in the column to include time of day descriptions to the images in column 1.

- Scenario A represents the Sun during a sunrise or sunset.
- Scenario B represents the Sun at noon.
- Viewing the container from eye level simulates how a person sees the Sun from Earth through the atmosphere.
- Viewing the container from above lets us see the path of the light through the atmosphere, as if we could imagine a "cutaway" view of the atmosphere.

Predict investigation outcomes.

If needed, display optional **slide E** to help students connect the investigation scenarios to the model of sunlight shining through Earth's atmosphere at different times of day.

Direct students to predict what they will see in the first two scenarios (plain water and adding the first ¼ tsp milk powder). They will make predictions about the third scenario during the investigation, just before they add additional milk powder.

3. Carry out the light and milky water lab.

14 MIN

Materials: Light and Milky Water Lab, *Investigation Elements Map, Predictions, and Results*, *Instructions for the Light and Milky Water Lab*



Work in groups to carry out the investigation. Display **slide F** and refer students to *Instructions for the Light and Milky Water Lab* for their procedures**.** Allow groups to proceed through each phase of the investigation.

Rotate among groups to check that students are:

- making observations at eye level and surface level;
- recording observations about both color and brightness; and
- using words like "more" and "less" and "brighter" and "dimmer" and color descriptions like "redder" or "bluer."

Probe group observations with questions like the following:

- *More than what? More than where?*
- *Less than what? Less than where?*
- *From which perspective? Above or side view?*
- *Dimmer or brighter than what—the plain water or somewhere else in the container?*
- *Where was the light redder? Where was the light bluer?*
- *Was that the same in all of your trials? Did you notice it more/less during a certain viewpoint or condition?*
- *Would the atmosphere always be like that then? All the time, everywhere?*

Assessment Opportunity

Building towards: 10.A Carry out an investigation to collect data as evidence of the effect of light interacting with a simulated atmosphere.

What to look/listen for: As students carry out the investigation, visit groups and listen for ideas such as these. You can also read their observations and responses to the questions on *Investigation Elements Map, Predictions, and Results* and compare them to the sample responses provided in *Investigation Elements Map, Predictions, and Results*.

- The light didn't change color in the clear water from any view.
- The light changed color in the milky water: from eye level, it looked yellower, oranger, and redder the more atmosphere (longer distance) or more particles in the atmosphere (greater density of particles) it was traveling through.
- The light was dimmer when it was shining through more atmosphere.
- Viewed from above, we can see bluish light in the milky water nearer the flashlight, and yellower/oranger/redder light as it moves through the atmosphere.

- Based on the results of their investigation of ¼ teaspoon of milk powder, students predict that the simulated atmosphere containing more particles (an additional ¼ teaspoon of milk powder) will cause the light to appear dimmer and redder/oranger.
- The light is interacting with the simulated atmosphere: something about the particles in the atmosphere is affecting the light.
- The light is being transmitted and reflected (scattered) differently—the bluish color is "getting out" (reflected/scattered), and the orangish color is "getting through" (transmitted).

What to do: If students need more support as you're visiting groups during the investigation, suggest they focus on color changes or brightness using prompts such as these.

- Color changes
  - The light started out white. Did it stay that way?
  - What colors did you see close to the flashlight? Farther away from the flashlight?
  - What do you think happened to the light to make it change that way?
- Brightness
  - Was the light from the flashlight just as bright after it crossed the container?
  - When and where was the light from the flashlight the brightest? When was it dimmest?
  - What do you think happened to the light to make it change that way?

If students need more support synthesizing their results and responding to the sense-making questions on *Investigation Elements Map, Predictions, and Results*, you might suggest two groups share materials and set up side-by-side views lengthwise and widthwise through two containers to directly compare and contrast the color changes and brightness differences they observe.

Clean up and record what we figured out from this investigation. Display **slide G** for cleanup directions (modified as needed for your classroom) and provide time for cleanup.

Display **slide H** and remind students to record their thinking in response to the final questions on their *Investigation Elements Map, Predictions, and Results* handout. Remind them to bring their handouts to the Scientists Circle.

4. Co-construct models to explain our investigation results.

13 MIN

Materials: *Investigation Elements Map, Predictions, and Results*, science notebook, sticky notes, Color Changes poster, chart paper, markers

Share investigation results and co-construct a model to explain them. Display **slide I**. Form a Scientists Circle and work to co-construct a model explaining the color and brightness changes we observed in the investigation. A sample model is shown after the discussion prompts. Say, *I heard so many exclamations and observations as you were working through the investigation. Let's get some of those big ideas on the table right now. What did you notice that you think most other people noticed, too? Turn and talk with a neighbor before we share with the whole class.*

Sample student responses:

- *The light turned orange (not white) when we looked at it through the milky water.*
- *The light was more whitish-yellowish through the short side of the container.*
- *The light was more orangish-reddish through the long side of the container.*
- *The light was really orange and much harder to see when we doubled the amount of particles.*
- *The light was brighter through the short side than it was through the long side.*
- *When you looked from the top, the light faded from blue to orange.*

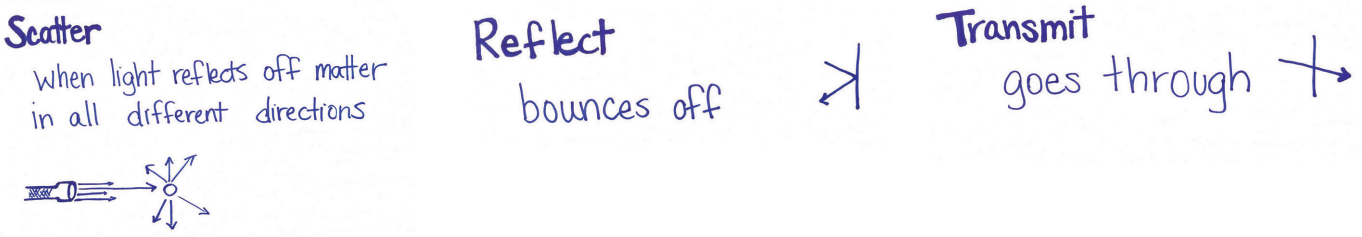
Probe deeper and consider the causes of these results using prompts such as the following.

Suggested prompts	Sample student responses
The light coming from the flashlight was white. What do you think happened to make white light turn orange?	*maybe the light is breaking up* *The light changes colors when it hits the milky water.* *I've heard that white light is a mixture of all the colors, so maybe only the red and orange "get through."*
Let's keep thinking through this. What was in our simulated atmosphere that might have affected the light we were seeing?	*The milk powder and the water.* *They are clearish-whitish molecules and particles.*
How could those molecules and particles affect the light? What might light do when it shines on them (or any object)?	*The light could reflect off the particles.* *They could let the light through (transmit it).* *They might absorb it.*
If light could be interacting with the particles in any of those ways, why do you think we saw different colors? Why blue near the light and orange farther away?	*Maybe blue light is easier to reflect.* *Maybe only the orange light could transmit through.* *The different colors of light interact with the particles in different ways.*
Maybe considering the brightness changes we saw can help us, too: Why do you think the light was dimmer after traveling through more matter? What could be causing that to happen?	*The more "stuff" the light had to shine through, the less of it could get through to our eyes.* *If the light is reflecting off the particles as it travels through the atmosphere, it's going in all different directions—away from its original path from the flashlight to our eyes. As it goes through more matter, more light is hitting particles and getting scattered away, so there's less light to see by the end.*

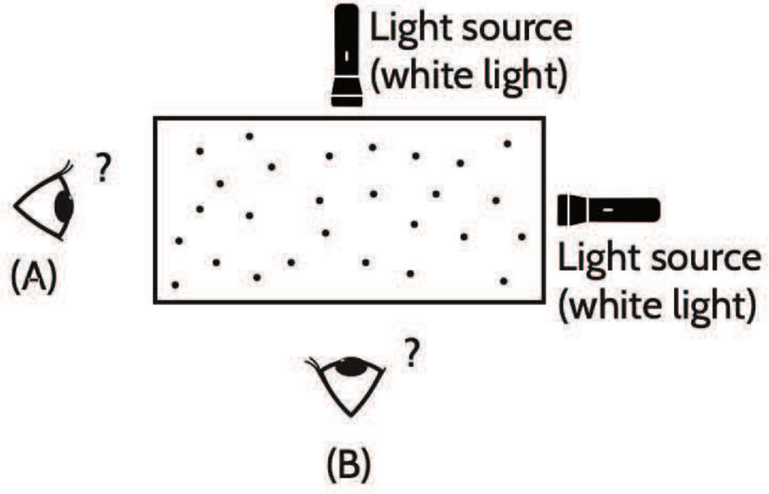
Name scattering. Say something like, *One thing I heard you saying was that at least some of the light is bouncing off or reflecting off the particles and molecules in the atmosphere and going in all different directions. We can use the word "scatter" to talk about that certain kind of reflection where the light ends up bouncing off in all different directions.*

Add "scatter" to your Word Wall. Your definition might be something like "when light reflects off matter in all different directions." See the sample image shown below.

If it's helpful, you may also want to repost "reflect" and "transmit" on your Word Wall after recalling their definitions from the *One-way Mirror Unit*. Sample Word Wall images from that unit are shown here:



As you build your Milky Water Atmosphere model, it will be useful to have your students consider both conditions: light passing through a longer length of atmosphere/more matter (like the sun at sunrise/sunset, condition A below) and light passing through a shorter amount of atmosphere/less matter (like at noon, condition B below).



Probe deeper into the color change observations. Say, *We noticed a blue color when the white light we started with interacted with the particles in our simulated atmosphere. Less light transmits through those particles, and that light that does get through looks more and more orange to reddish in color. How can there be colors in that white light that we didn't see before?*

Accept all responses, which may or may not include ideas such as the following:

- *White light has all the colors in it already.*
- *White light can "split up" into different colors.*
- *It has something to do with rainbows.*

Navigate to next time's work. Say, *We have some interesting ideas about both white light and the colors of light we see. Why are those colors there after light passes through matter? Next time we're together, let's dig into some of our related phenomena to help us better understand light and color.*

If time allows, direct students back to their desks to record additional related phenomena ideas on sticky notes of other times they have seen light split into different colors or mix to create new colors. Add these ideas to the Color Changes poster.

Assign optional home learning. Display **slide J**. Ask students to share with their family and/or friends what they figured out today about light changing colors when it passes through matter. Have them brainstorm other phenomena where they have noticed white light breaking up into different colors or changing colors. Direct students to jot down these ideas to bring to class tomorrow. Consider inviting students to find and bring images of light breaking into colors to help describe their related phenomena.

LESSON 11

How does the shape of a water droplet or an ice crystal cause sunlight to form into a rainbow?

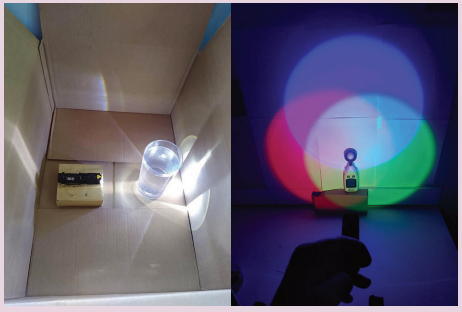
Previous Lesson

We investigated the color and brightness changes we see as light travels through the Earth's atmosphere by using a flashlight to simulate the Sun and a rectangular bin of milky water to simulate the atmosphere. We co-constructed a model of light transmitting and scattering through the simulated atmosphere based on our investigation results.

This Lesson

Investigation

2 DAYS



We investigate times, places and perspectives needed to see white light split into its many component colors—making a rainbow. We investigate the effect that different materials and their shapes have on (white) light—causing it to change direction (refract) and sometimes make colors and rainbows. We conduct another investigation to recombine colors of light. We discover that combining light in different ways can change the overall color and brightness of the light that you see.

Next Lesson

We will evaluate models created in those lessons before we co-construct a new model of what is happening during a lunar eclipse. We will prepare for and complete a transfer task.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

11.A Conduct an investigation to collect and produce data as evidence to answer scientific questions about relationships of light interacting with differently shaped objects of varying compositions.

11.B Develop and use a model to describe the separation of white light into different colors (effect) as it travels through different mediums (cause).

What Students Will Figure Out

- When light interacts with water and/or glass of certain shapes and at certain angles, it can produce a rainbow.
- What you observe is dependent on the perspective of the observer.

- Each color in the rainbow that is produced is less bright than the light that reaches the water/glass; the path that each color of that light follows is a straight line after it leaves the water or the glass.
- Materials like water or glass must be able to separate the white light into different colors and change their path based on what color they are.
- White light is a combination of different colors (e.g., red, green, and blue).
- Combining different colors of light together results in more intense light (brighter).

Lesson 11 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION** Review the Lesson 10 consensus model for the effects of the atmosphere on light and connect to other light scattering phenomena.	A-B	Patterns and Phenomena in the Sky poster, markers
2	5 min	**ANALYZE COLOR-SPLITTING IMAGES** Observe images of rainbows and other light-splitting phenomena to consider patterns of similarities and differences.	C	
3	8 min	**ANALYZE THE SHAPES OF WATER DROPLETS AND CRYSTALS IN OUR ATMOSPHERE** Students watch slo-mo video of water drops falling and compare the shape to ice crystal shapes from static images.	E-G	8.4 Lesson 11 Shape of Water Drop (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	8 min	**PLAN AN INVESTIGATION** Students brainstorm possible outcomes when light shines on various shapes.	H-J	The Rainbow Lab
5	18 min	**CONDUCT THE RAINBOW LAB** Students will rotate through lab stations investigating the effect of shape on the path and color of light.	K	*Example Images Path of Light* (optional), *Suggested Prompts for the Rainbow Lab Investigation*

End of day 1

Part	Duration	Summary	Slide	Materials
6	5 min	**ANALYZE AND INTERPRET OUR DATA** Students recall data from the Rainbow Lab and share with a partner to compare observations.	L	
7	14 min	**DEVELOP A MODEL** Develop a model for the direction and color of how a beam is affected by passing into and out of a new medium.	M	colored pencils, *Example Images Path of Light* (optional), 8.4 Lesson 11 Refraction Path of Light (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional)
8	6 min	**APPLY THE REFRACTION MODEL TO A NEW PHENOMENON** Students apply a co-developed refraction model to the prism or another example of their choice.	N	colored pencils, rulers, paper (or science notebook)
9	12 min	**INVESTIGATE WHAT HAPPENS WHEN COMBINING COLORS OF LIGHT** Students will demonstrate that by recombining separate colors of light, we create new colors and brighter light. Students will combine red, blue, and green light to create white light.	O-P	*Sample Images: Combining Light Demonstration*, Combining Light Investigation
10	5 min	**UPDATE PROGRESS TRACKER** Students update their individual Progress Trackers.	R	colored pencils
11	3 min	**NAVIGATE** Consider how these discoveries might help explain the red Moon during a lunar eclipse.	S	
				End of day 2
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 11, students are ready to read Student Reader Collection 3 and then respond to the writing exercise.		Student Reader Collection 3: *Imaging and Imagining Space*

Lesson 11 • Materials List

	per student	per group	per class
The Rainbow Lab materials	• *Rainbow Lab Instructions and Data Collection* • safety goggles	• *Reading - Podcast: Thebe Medupe - Rebirth of Selemela*	• 2 clear round glass tumblers • 2 clear hexagon glass jars with lids • 2 small mirrors (about 4 inches wide) • 2 clear shallow bowls wide enough to hold one of the mirrors (about 5–6 inches wide) • 8 (or more) flashlights (preferably bright and incandescent (not LED)) • 8 12″ rulers • blue painter's tape • 8 copy paper or file boxes • 2 copy paper or file box lids • 8 small blocks or books about 1–2 inches thick • solid triangular glass prism
Combining Light Investigation materials	• *Combining Colors of Light Data*	• *Combining Light Investigation* (optional)	• green light flashlight • red light flashlight • bluelight flashlight • batteries for the flashlights • white paper or similar background • digital light meter
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• *Example Images Path of Light* (optional) • colored pencils • science notebooks • rulers • paper (or science notebook)	• colored pencils	• Patterns and Phenomena in the Sky poster • markers • 8.4 Lesson 11 Shape of Water Drop (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Suggested Prompts for the Rainbow Lab Investigation* • *Example Images Path of Light* (optional) • 8.4 Lesson 11 Refraction Path of Light (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • *Sample Images: Combining Light Demonstration*

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Shape of a Water Drop video 8.4 Lesson 11 Shape of Water Drop (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) and optional Refraction of Path of Light video 8.4 Lesson 11 Refraction Path of Light (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Day 1: The Rainbow Lab

- **Group size:** 3–5 students
- **Setup:**
  - Refer to *Preparing for the Rainbow Lab* for specific instructions about setting up the stations used in this lab.
  - Darken the room as much as possible.
  - If your students have access to water in the classroom, you might direct the first group at stations 1, 2, and 3 to fill their containers with water for themselves and the following groups to use. If no water access is available in the classroom, you will need to fill the glasses, jars, and bowls before students come in.
- **Notes for during the lab:** None
- **Safety:**
  - Use indirectly vented chemical splash goggles and non-latex aprons during the setup, hands-on, and takedown segments of the activity.
  - Immediately pick up any liquid spilled on the floor in the work zone so it does not become a slip/fall hazard.
  - Use caution when working with water - keep clear of any electrical receptacles or electrical equipment to protect against shock hazards.
  - Flashlights can produce intense light levels. Do not look directly at the light source to prevent eye injury.
  - Use caution when working with glassware (glass tumblers, mirrors) which can shatter if dropped and cut skin.
  - Have students ask the teacher where to safely place equipment/materials upon completing the lab activity.
  - Have students wash your hands with soap and water immediately after completing this activity.
- **Disposal:** Water can be disposed of down the drain.
- **Storage:** Flashlights should be turned off when not in use to preserve batteries. At the end of the unit, remove the batteries and store flashlights per manufacturer's directions.

Day 2: Combining Light Investigation

- **Group size:** Whole class with individual student volunteers
- **Setup:**
  - Check all three red, green, and blue flashlights to make sure the batteries are good. Consider replacing if necessary. Lux values should be similar to the values in *Sample Images: Combining Light Demonstration*.

- Tape a large white sheet of paper to a wall in a darker area of the room (the darker the better). A white wall will also work.
- Darken the room as much as possible.

- **Notes for during the lab:** Provide time for students to record results. Solicit different volunteers during each trial to get more kids involved.
- **Safety:** Flashlights are bright, especially when the beams are focused. Avoid shining directly into the eyes.
- **Disposal:** None
- **Storage:** Flashlights should be turned off when not in use to preserve batteries. At the end of the unit, remove the batteries and store flashlights per manufacturer's directions.

Lesson 11 • Where We Are Going and NOT Going

Where We Are Going

Students will observe that white light interacting with matter can, but doesn't always, separate into different colors of visible light. Observable interactions that students will determine are occuring will include reflection (bouncing off a surface in a uniform direction), refraction (changing the direction of travel when passing from one medium to another), and scattering as a special case of reflecting (in many different directions). Students will notice independent colors (wavelengths - term not used with students) refract at different angles, creating the separation of colors they see appearing in different locations from a source of white light. The amount of refraction is dependent on several factors, including the type of matter, the amount of matter, and the state of matter the light encounters. Students will use these ways that light interacts with matter to construct a model at the end of this lesson that will help them explain the lesson set question "Why is the Moon red during a lunar eclipse?" in Lesson 12.

In addition to refraction and reflection, students will take notice of the relative brightness of the light before and after refraction and then build on that understanding by participating in a whole class interactive demonstration where they will recombine colors of light to "rebuild" white light. While recombining light in the second activity, they will add to their color-specific knowledge by learning how different colors can be created by combining specific colors of light. During the recombination demonstration, students will measure brightness using a light meter, which will confirm the anecdotal evidence that specific colors of light are less bright than white light, which is a combination of many separate colors.

In this lesson, students access specific prior knowledge they bring in from the *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* and Lesson 10 when they learn that when light shines on an object, it can be reflected or transmitted. Students will rebuild their connection to *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* by connecting that the color of light we see is due to light reflected to and transmitted to the back of the eye. Students may also bring in some prior knowledge about refraction if they participated in the optional extension activities about refraction during the *One-way Mirror Unit*, but that prior knowledge is not necessary for the work students do in this lesson.

Reminder about supporting students with visual disabilities: In this lesson, students analyze the refraction of white light as well as the recombining of colored light into white. Students who are color blind may or may not be able to differentiate among some or all of these colors of light, and if they can, their view of the colors will be different than that of their classmates. So, you will need to make accommodations so that students with this and other visual

disabilities do not experience barriers to the investigations in this lesson. Your students' IEP or 504 case leaders should also be able to provide you with specific resources and possible modifications to use.

Where We Are NOT Going

In this lesson, students will not be measuring or collecting data on angles of refraction. Only qualitative data will inform students about which colors refract more (e.g., violet and blue) and which refract less (e.g., red). No attempt is made to discuss the term wavelength nor these associated properties of light waves, as the frequency and wavelength of a light wave is due to the properties of propagating an electromagnetic field and is a level of understanding that is reserved for high school. Similarly, we do not name the specific angles of reflection or refraction involved in a specific shape to create the rainbow effect but simply measure the resulting qualitative effects—shifts in the location and brightness of colors—due to shifts in the path of where light separates into different colors or crosses and recombines.

LEARNING PLAN FOR LESSON 11

1. Navigation

6 MIN

Materials: Patterns and Phenomena in the Sky poster, markers

Navigate into today's work. Display **slide A**. Revisit the Milky Water Model developed at the end of Lesson 10. Briefly review the main ideas about color and brightness changes. Probe for key ideas by asking "What did we see yesterday when we shined white light on our simulated atmosphere?" Look for these responses:

- *Before the light hit our milky water atmosphere, the color was white.*
- *The light changed from white to red/orange.*
- *Blue light seemed to reflect out earlier than red light.*
- *The light got dimmer as it passed through the atmosphere/milky water.*

Discuss Related Phenomena. Display **slide B.** Have students open science notebooks to the brainstorm of related phenomena done in class or at home. Provide a minute for them to share their phenomena with an elbow partner before sharing out as a whole class. Record related phenomena on a separate poster to be placed or added near the original related phenomena poster from Lesson 1. Some likely related phenomena might include the following:

- *Rainbows: These may have multiple sources.*
  - *After a rainstorm*
  - *From a garden hose*
  - *From a waterfall*
  - *In a water park*
- *Sun dogs*
- *From crystals, like in a sunny window*
- *Oil/Gas on the street (or in the water)*

- *Sun shining through glass*
- *Sun reflecting off water*
- *Double rainbows, inverted rainbows, full circle rainbows*
- *Moonbows*

Say, *It may have been a while since we have seen some of these amazing phenomena. Let's take a couple of minutes to look at some images to remind ourselves of their beauty as well as to look with our science eyes for patterns and common features.*

2. Analyze color-splitting images.

5 MIN

Materials: None

Analyze images of light-splitting (rainbow) phenomena. Display **slide C.** Say, *here are some different images of ideas you suggested about when we see light split up into colors and one you may not have thought of. Let's review what we're looking at for just a moment*. **Briefly describe each image to the students.**

- A double rainbow over a farm field
- A single rainbow
- Sun in a freezing winter sky (Sun dog). Say, *This effect can happen even when there are relatively few water particles in the air and it's really really cold, as long as those particles are frozen into ice crystals.*
- Waterfall spray forming a rainbow
- Spraying water from a garden hose showing a rainbow

Additional Guidance

If and when possible, please consider swapping in these images with ones situated in your location and community. Consider the places your students will have encountered rainbow phenomena, and if possible, insert pictures that they will connect to. This will help build their sense of place and a stronger connection to their lived experiences in their own community.

Prompt students to think deeper. Display **slide D.** Say, *It may have been a while since some of us have seen some of these phenomena. Let's analyze. What do we notice or wonder about these phenomena? What things do they appear to have in common? What differences do you notice? If we consider perspective, what has to happen for us to view these phenomena?*

Suggested prompt	Sample student responses
What do these images have in common?	*All involve water in some way.* *The Sun is shining in every image.* *The colors follow a predictable pattern (ROYGBIV).* *They all take place in the sky (within the atmosphere).* *The rainbows are related to weather conditions.*

Suggested prompts	Sample student responses
What differences do you notice? Is there an image with something unique?	*A Sun dog is smaller, has fewer colors.* *A Sun dog creates multiple suns.* *The secondary rainbow's colors are reversed.* *The garden hose rainbow is much smaller.*
What is the light source that is producing all of these phenomena?	*the Sun*
Let's consider perspective, where do you think the Sun is in these images compared to the water and the observer?	*Rainbows (for all sources)* • *Sun behind you, rain/spray in front* • *Facing away from the Sun* *Sun dog* • *Sun in front of you, ice crystals in front* • *Facing the Sun*

Additional Guidance

Your students may realize that in nature most of the phenomena we describe occur when some kind of matter interacts with full spectrum sunlight. Later in this lesson, students will use flashlights to provide a similar spectrum of light. Modern LED flashlights (if used) do not contain all wavelength colors in the same proportion as an incandescent bulb or sunlight, but should be sufficient for simulating a close approximation. The resulting rainbow color spectrum will sometimes be dull, or entirely lacking, in some colors of light that you might find in a sunlight-produced rainbow.

Additional Guidance

If you feel that your class is having trouble imagining or coming to agreement on the perspective needed to see a rainbow, it may be useful to take a moment to sketch the different orientations that create rainbows or Sun dogs. Perspective or orientation can help students who are grappling with ideas of reflection, refraction, and scattering. It is also useful to reference the model developed in Lesson 5 from *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* to remind students that what we see or perceive is from light entering our eye. POL (path of light) models are more useful than LOS (line of sight) models when describing light-related phenomena.

3. Analyze the shapes of water droplets and crystals in our atmosphere. 8 MIN

Materials: 8.4 Lesson 11 Shape of Water Drop (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Draw the shape of a water drop. Display **slide E.** Say, *Clearly when light hits these particles of water at a certain angle, we get a rainbow. So, what is special about water droplets? If you could zoom in on one of these, what sort of shape would you picture they have?* Ask students individually to draw what they think a water drop or drops looks like when falling from the sky into the left side of a new page in their science notebook titled *The Shape of Water.*

Analyze videos. Say, *Luckily, many people have captured slow motion video of raindrops falling. Let's watch one of those videos now to see if a real raindrop matches our ideas.* As students watch the video 8.4 Lesson 11 Shape of Water Drop (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), have them sketch what they are seeing. Play the video twice.

Problematize solid vs. liquid water shapes. Say, *It seems like raindrops may not be the shapes we thought. I wonder if our ideas about solid precipitation might also need revising. In the cold upper atmosphere there are often ice crystals instead of liquid water. Let's look at a collection of ice crystal images and see what we find. What do you think they will look like? Draw a quick prediction directly under your raindrop prediction from earlier.*

Display **slide F.** Give students a minute or so to contemplate the various shapes. Have a short discussion of their noticings regarding the shapes of ice crystals. Acknowledge that there are many kinds and many differences, but probe students to look for similarities in geometry. Some expected responses might include the following:

- *Flat faces and or edges (and or 6 sides)*
- *3 dimensional*
- *Either have points or flat surfaces*
- *There are a lot of different shapes/possibilities.*
- *They are not round like water.*
- *Most don't look like snowflakes.*

Display **slide G.** Read aloud the questions on the slide. *If we wanted to test out the effects of light on different shapes and types of matter, what are some things we could try?* What conditions would we need to recreate? Allow time for a few responses to motivate the next investigation.

Sample responses

- *We need objects of different shapes.*
- *We need a light source.*
- *We might need water … and ice?*
- *We have to figure out how to get this all to help us see, produce, or project a rainbow in the classroom.*

4. Plan an investigation.

8 MIN

Materials: The Rainbow Lab

Prepare to try to create rainbows. Display s**lide H.** Say, *Let's prepare to test our ideas about how light might interact with all of these different geometries. We can scale up the size of the "droplets and crystals" to do some investigations in class. I have these round glasses and these hexagonal jars.* Give students a minute and a half to talk through the predictions on this slide.

Display **slide I.** Say, *In addition to these shapes, we also have a round bowl with a mirror and a solid glass triangular prism.* Give students another minute and a half to talk through the predictions on this slide. Share the basic box and light setup for each station with students. Explain that the purpose of the box is to let us capture light no matter what direction it goes after interacting with our objects.

Make predictions about what we will see in the boxes. Ask students to turn and talk with a neighbor about what they think will happen when we shine white light onto the round and hexagonal glass structures filled with water. Allow a couple of minutes for partner talk, and encourage discussions on how they might explain their responses. After 1–2 minutes, invite a few students to share out in the whole group. Probe and push on responses. Some suggested prompts are below.

Suggested prompts	Sample student responses
Do you think we will see white light or colors?	*Colors because when we see rainbows in nature, we see all of the colors.* *White light because it's just a glass filled with water.* *White light because it's not in drops or spray form.* *White light because the jar isn't really ice; it's just glass, which is different.*
Will we see all or some of the colors?	*If we see colors, we will see them all.* *Maybe it depends on the light.* *Some but not all because some colors are really hard to see, like purple and maybe red.*
If we see a rainbow, will it look like other rainbows we've seen or be different?	*Different—it won't be in the air.* *Different—maybe we won't see the whole arch.* *Same—I think we'll see the same colors.* *Similar to a rainbow from crystals or prisms.* *I'm not sure what to expect.*

Suggested prompts	Sample student responses
Will the rainbow be brighter than the white light?	*Maybe, because we can see all of the colors at the same time.* *No, the light will be more spread out so it can't be brighter.* *Yes, because blue light and green light are brighter than other colors.* *That's why we have blue light filters at night on our phones or computers.*
How do you think the shape of the glass will affect what you see?	*I think the colors we see will be the same.* *I think where the light goes will be different, to different places.* *I think the colors will be the same but they will be in different places.*

Prepare for the investigation. Distribute *Rainbow Lab Instructions and Data Collection* and give students 2 minutes to trim and tape it into their science notebooks (or keep it loose if you wish to collect it for assessment).

Introduce procedures to students. Display slide J. Say, *At each lab station you will find a box, a flashlight, a small block or book, and the object. The box will be our screen, allowing us to view results anywhere they appear. The blocks will hold the flashlight so you can be "hands free" in order to observe and take measurements. At each station there will be a slightly different geometrically shaped object, some containing water, but it won't be in the path of light yet. Turn the flashlight on. Mark the center of the beam on the box with a small piece of blue tape. Slide the object (glass, jar, prism, or bowl with mirror) into the beam of light. Move the object around, testing various distances, angles, and geometries. Write observations of what you see. Especially take note of the type (color) of light you see as well as the location of each color.*

Display slide K and review the directions for this lab.

At every station

- *Turn the flashlight on.*
- *Mark the center of the light beam on the box with a small piece of blue tape.*
- *Slide the object (glass, jar, prism, or bowl with mirror) into the beam of light.*
- *Record any changes you noticed in this condition for*
  - *the position of where the beam of light falls, and*
  - *the color of the light at that position.*

When you have time

- *Move the object around, testing various distances, angles, and geometries.*
- *Write observations of what you see.*
- *Take note of the type (color) of light you see as well as the location of each color.*

5. Conduct the rainbow lab.

18 MIN

Materials: *Example Images Path of Light* (optional), *Suggested Prompts for the Rainbow Lab Investigation*

Conduct the Rainbow Lab Investigation. Divide students equally into 8 groups. Keep **slide K** displayed**.** Call student's attention to the "OK to change" and "do not change" instructions on the slide. After their initial observations, they can adjust the positions of the various objects to see if they can "improve" on the initial result. Once they have their best orientation of objects, they should add those observations to their handout using words and pictures. Provide a one-minute warning before the end of the station so students can take all materials back out of the boxes and leave a clean lab station for the next group, including removing their tape marks. Students should repeat the process at each of the stations until all stations are completed.

Assessment Opportunity

Building towards: 11.A Conduct an investigation to collect and produce data as evidence to answer scientific questions about relationships of light interacting with differently shaped objects of varying compositions.

What to look/ listen for: Monitor groups at the stations and look/listen for their observations about the three key ideas: path of light, color changes, and brightness of light.

What to do: At each lab station and for each lab group, prompt observations by asking focusing questions around the key observational data sets. See *Suggested Prompts for the Rainbow Lab Investigation* for suggested questions to ask for each data set. If time permits prior to Day 2, observe student understandings by reading or collecting their responses to the reflection questions on *Rainbow Lab Instructions and Data Collection* to check for understanding of patterns.

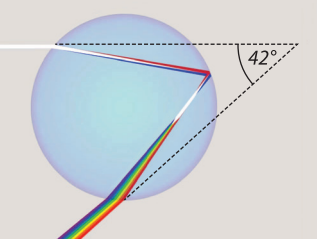
End of day 1

6. Analyze and interpret our data.

5 MIN

Materials: None

Additional Guidance



The refraction of light into color bands is due to different wavelengths of light refracting (bending) at different angles when passing through the water droplets. The refracted light then reflects off the back wall of the water drop and travels to our eye, resulting in the rainbow effect. The specific refraction angles of light are not specifically referenced in this lesson, but your students may question why or how white light becomes the colors of the rainbow. Without getting into specific wavelength descriptions, simple terms such as *red light bends (refracts) more* and *blue light bends (refracts) less* will help build a sufficient explanation for why white light can separate into a many colors (a rainbow) when its path travels into or out of a different medium (water or glass).

Begin data analysis/review. Display **slide L**. Say, *Yesterday at the end of class, we had the chance to observe white light passing through a variety of shapes and mediums. Let's review that data you collected with a partner to see if we can find any patterns.* Read the prompts on the slide to focus student attention on the three variables.

- What happened to the *path* of light as it passed through the different geometries and mediums?
- What happened to the *color* of the white light as it passed through different mediums and geometries?
- What happened to the *brightness* of the light as it passed through different mediums and geometries?

Provide a few minutes for students to revisit the scenarios. As students discuss, circulate the room. Push students to move beyond generalizations like "it formed a rainbow" to looking in more specific details, such as it formed a rainbow and I could see the red, yellow, and purple but not the blue or orange. Some suggestions for prompts/questions might include the following:

- Did you see all of the colors of the rainbow, or were some missing?
- How did you know the light path changed? What evidence supports that idea?
- What colors appeared dimmer? Brighter? How did you know they were dimmer or brighter?
- Were all the rainbows the same? Did they all have the same appearance?
- Did the light move in the same way for every geometry? Was one more pronounced than another?

Additional Guidance

During this review and subsequent discussion, students may have additional observations about the size of the rainbow effect. They may also puzzle over missing colors from their rainbows. Depending on the brightness of the room, type of light, and cleanliness of the glassware, different effects might be observed. Acknowledging these observations is important but to a lesser extent than the key concept of refraction (bending) of light as it passes through a medium and the separation of light into respective colors.

7. Develop a model.

14 MIN

Materials: colored pencils, science notebooks, *Example Images Path of Light* (optional), 8.4 Lesson 11 Refraction Path of Light (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) (optional)

Acknowledge student work and ideas. Display **slide M.** Say, *As I visited the different groups I could tell that you certainly noticed and found evidence for some interesting things the beam of light was doing as it passed through these different objects. Let's try to capture some of these interactions by drawing out at least one of those conditions.*

Form a Scientists Circle. You can choose any of the scenarios explored the previous day, but to make a stronger connection to the lunar eclipse phenomena and effects of the atmosphere on light, we suggest using one of the lab stations that included water. Work together with your students on chart paper or the board to annotate the image together. A sample image and annotation is provided.

Key Ideas

Purpose of this discussion: Develop a model to explain what happens to light as it passes through different objects.

Listen for these ideas.

Be sure to indicate these five locations in the model.

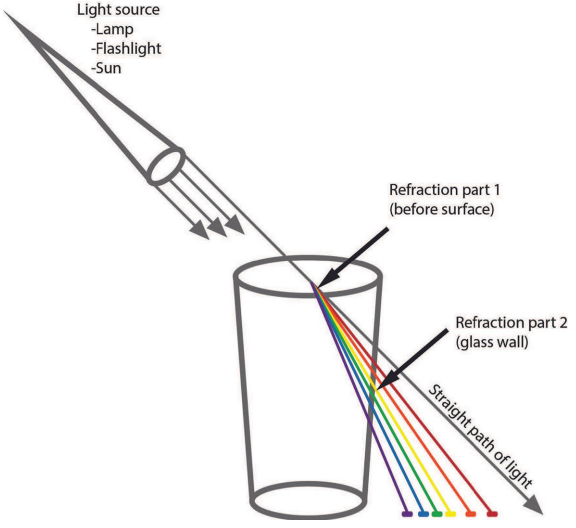
- Label the light source.
- Identify the direction of the white light, including where it would have gone if no matter was in its path.
- Identify the point at which its direction changed.

In our lab scenarios, the light would have changed direction twice: once when it passed into the water and again as it passed through the glass. You can choose to include both or simplify the annotation by only including the surface of the water.

- Show the separation of at least 2 colors in slightly different directions.
- Show that those directions result in a different color in a different part of the surface.

Note: Students will have seen evidence that different colors of light have slightly different angles of refraction; that's why we can see the colors spread out from the white light. However, students may ask why different colors have those different angles of light. You may choose to respond with something like, *That's such an interesting question! We won't figure that out this year, but you can certainly investigate it on your own, and you'll get to explore light and colors more in high school.* At this point, students don't have a wavelength-based model for light like they do for sound, so we don't want to just tell them the refraction is because of the different wavelengths of the light.

See one example of this model.



Suggested prompts	Sample student responses	Follow-up questions
What was our light source? Where was the light coming from?	*the flashlight* *the Sun* *the lights in the room*	*Would any light source work?*
What color was the light coming from the source?	*white* *all of the colors*	
What was the color(s) of the light we saw after passing through the medium?	*a lot of different colors* *the colors of the rainbow* *most of the colors of the rainbows but some were missing* *It was a little different, depending on which medium/materials we shined the light on.*	*Did you notice any patterns depending on which color of light fell where on the surface it shone?*
Wait … the light started out white and became colorful? Where do you think that change happened?	*When the light hit the water, it changed.* *When the light went through the glass, it changed somehow.*	*What do you mean? Can you say more?* *Did you mean as soon as it hit the water (the surface) or in the water (deeper in)?* *Are you thinking the light changed instantly when it entered that matter or that it changed gradually over time as it traveled through it?* *Do you think it changes when it hits the glass or moves through the glass?* *Does it change at the glass surface, inside, or as it leaves?*
Did all of the light/colors bend the same amount?	*maybe* *No, because then we would have seen white light on the other side.* *No, the red ended up in a different place than the blue.* *None of the light stayed on the path; they all bent, just not the same amount.*	*Are you saying all of those colors came out of white light?* *What do you mean by a different place? How might that happen?* *How did you know that? What evidence did you gather to support that idea?*

Suggested prompt	Sample student responses	Follow-up questions
If the path they traveled was changed by different amounts, then which colors had their direction of travel change (or bend) the most? Least?	*Blue and violet bent the most.* *Red bent the least.*	

Additional Guidance

In this teacher guide, you will see refraction of light referred to as light "changing direction" instead of "bending." Describing light as bending may communicate to students that light curves. Unlike how a metal rod or a straw might bend, or curve, light does not. Rather, it travels in straight lines, but it can change direction as it moves between transparent materials, which makes it appear to bend. When discussing this concept, carefully choose how you will describe refraction. You can choose to use either "changing direction" or "bending," or both, but make sure you use language that will give students an accurate mental image of what light is doing as it moves through different transparent materials. For additional guidance watch 8.4 Lesson 11 Refraction Path of Light (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) or see the still images on *Example Images Path of Light*.

8. Apply the refraction model to a new phenomenon.

6 MIN

Materials: colored pencils, rulers, paper (or science notebook)

Use the Refraction Model to explain a new phenomenon. Display **slide N**. Say, *This is really interesting. I wonder if this model could be used to explain the other scenarios we investigated, like the prism or the bowl and mirror setup. Let's give it a try. Select one of those two phenomena to model on your own. Before you begin, what is going to be important to include?* Co-construct a quick Gotta-Have-It checklist for students to use as they develop their new models. This list should include the following:

- Light travels away from a light source in straight lines.
- That direction of travel can shift/change when it enters a new medium (its angle of travel can change); some colors of light change direction more than others when this happens.
- When it shines on a rough object (screen) and makes an image, that light reflects/scatters off that object (screen) in all directions.
- When it shines on a smooth object (mirror), that light reflects off in one direction.
- Light coming from an image or object must reach our eyes in order for us to see it.

Emphasize that the model should account for any changes in color or brightness in the light that they observed in the phenomena.

Additional Guidance

The ideas that when light shines on a rough object (screen) and makes an image, that light reflects/scatters off that object (screen) in all directions and that when it shines on a smooth object (mirror) that light reflects off in one direction is one students developed in *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)*.

If students choose to model the prism, they will create a model without water, and this will help the class develop the idea that refraction can occur through any transparent medium, solid, or liquid. This is important in helping students develop their ideas of both liquid and solid particles in our atmosphere affecting both the scattering and refraction of light.



Assessment Opportunity

Building towards: 11.B. Develop and use a model to describe the separation of white light into different colors (effect) as it travels through different mediums (cause).

What to look/listen for: Students should include that light passing from the light source to the prism is travelling in a straight line. Upon entering the prism, the light angle should change and the respective colors begin to separate. The light should bend again when leaving the prism and returning to air. Once in the air, the respective spectrum colors should continue in straight lines until reflected off of another surface (like the box in their investigation). This reflected/scattered light should then travel in straight lines to the person's eye. Students should note that the light broken into colors is less bright than the white light.

What to do: As students work to apply their model, move about the room asking probing questions for specific points in their models. Some suggestions include the following:

- What is happening the moment when light enters the prism?
- Does anything change when the light leaves the prism?
- Are all of the individual colors of light affected the same?
- How are you showing that the direction of light can change, and yet every part of its path is made of straight lines?
- Which colors of light seem to end up having their direction of travel changed more?
- Which colors of light seem to end up having their direction of travel changed less?
- How are you representing changes in light intensity (brightness) in your model?
- Are any colors brighter than other colors?
- How do we see the colors? How do they get to our eyes?

9. Investigate what happens when combining colors of light.

12 MIN

Materials: Combining Light Investigation, *Sample Images: Combining Light Demonstration*

Navigate into recombining colors. Display **slide O**. Briefly ask students to re-voice what they discovered during the rainbow lab. Pose the question, *If we can separate white light into colors, what do you think we might see if we tried recombining the different colors back together?*

Ask for a show of hands of students who have some ideas of what we might see happen. Say, *Before I have any of you share, I'd like everyone to consider this question further and make some quick predictions with a partner.* Show **slide P.** Read through the prompts on the slide. Give 1–2 minutes for students to turn and talk and then solicit a few ideas from the group.

Sample student responses

- *The light will be lighter.*
- *We may see many different colors than were there before when they mix.*
- *The light will be brighter.*

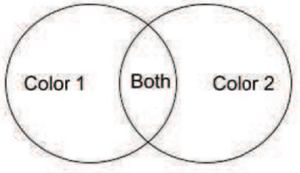
Prepare to investigate combining colors as a class. Still showing **slide P**, distribute *Combining Colors of Light Data*. Have students start a new page in their notebooks titled "Combining Colors of Light" and attach the handout there. Show the students the flashlights and click each on so they see each light color.

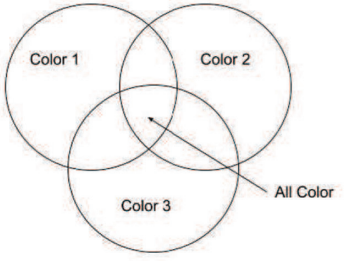
Establish procedures for the investigation. Display **slide Q** and discuss how to be sure this is a fair test. Focus on the need to keep as many variables consistent as possible, including the position of the light meter, the distance from the flashlights to the light meter, and the angle of light to the light meter.

Darken your classroom as much as possible and collect baseline data. Invite students to participate as you work together to collect brightness control data (lux readings) for each individual color—red, blue, and green. Invite pairs of students to test each individual color with one student operating the flashlight and the other taking lux readings using the light meter.

Say, *Now that we have some baseline data and before we start combining colors, make some predictions on your lab handout about what you think we'll see in terms of colors and brightness when we start combining light colors.*

Conduct the investigation. Ask three students to come forward to test a pair of the colors. Two students will create a Venn diagram-style image with the two flashlights similar to the one shown here. The third student will place a light meter where the colors combine in the center. Direct students to record on their handout any new colors that appear along with the new brightness. Compare this to the brightness of the light of just one of the colors. Repeat this process with different trios of students until all color pairs have been tried and data recorded.





- Red and green
- Green and blue
- Blue and red

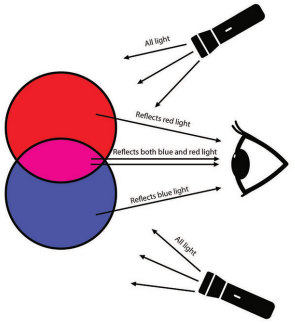
Conduct a final test to combine all three colors. Following the same procedures and protocols, finish the interactive demonstration by having four students come up and direct the three flashlights to form a final combination with all three colors of light as shown here. The fourth student should measure the lux. Record data as before.

Alternate Activity

If you have sufficient time and flashlights, have students conduct this investigation in groups of 4. Instead of one set of materials per class, you would need each group to have the same materials as the whole group demonstration. You can use *Combining Light Investigation* as a guide for your student groups.

Additional Guidance

Students may have questions about why combining colors of light produces a new color. If necessary, work with students to create a path of light model to support their thinking. One possible example is shown below. If student questions focus specifically on what is happening in their eyes that allows them to see the light as a new color, refer them to the reading from *Unit 6.1: Why do we sometimes see different things when looking at the same object? (One-way Mirror Unit)* Lesson 6.



10. Update Progress Tracker.

5 MIN

Materials: colored pencils

Update Progress Trackers to reflect new understandings. Present **slide R** and ask, *What have we figured out about light and color in our atmosphere?* Have students add their new understandings to their Progress Trackers. Sample entries are shown in the sample Progress Tracker below.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
How does the shape of a water droplet or an ice crystal cause Sunlight to separate into a rainbow?	• White light or sunlight gets broken into rainbows when it encounters water drops and ice crystals in the atmosphere. • Different colors of light refract differently. They don't all bend at the same angle. That's why they appear in order. • The separate colors are less bright than the combined white light. • If we put the separated colors back together, we can see white light again.	There are many times when we see rainbows and light of different colors. This activity helps me understand why I See rainbows and other colors.

11. Navigate.

3 MIN

Materials: None

Connect to the color-related phenomena of the Moon and Sun. Say, *now that we made all of these discoveries related to light and its interaction with matter related to color, let's start to consider how these might help us explain things we had questions about related to the Sun and Moon. Let's consider the Moon-related ones first.* Show **slide S.** Read the question on the slide. Give students 2 minutes to discuss this with a partner.

Say, *Next time, let's make sure to reserve some time to share out some of these ideas with the whole class so we can come to a consensus on which of these ideas we all think are key to use in helping us explain this question we had about the Moon. After that, we can take some time to try those ideas out in a revision to our initial model of what happens to light from the Sun during a lunar eclipse.*

SCIENCE LITERACY: READING COLLECTION 3

Imaging and Imagining Space

1 **Sparking the Imagination**
2 **Taking a Long Look**
3 **Our Pale Blue Dot**
4 **Beyond Photography**
5 **Out of the Shadows**

Literacy Objectives

- ✓ Distinguish cause(s) and effect(s) related to point of view and historical perspectives.
- ✓ Translate text to visual/graphic representation of ideas.

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 8: What does a lunar eclipse look like and how can we explain it?
- Lesson 9: Why do the Moon and Sun appear to change color near the horizon?
- Lesson 10: How does light interact with matter in the atmosphere?
- Lesson 11: How does the shape of a water droplet or an ice crystal cause sunlight to form into a rainbow?

Instructional Resources

Student Reader



Collection 3

Science Literacy Student Reader, Collection 3
"Imaging and Imagining Space"

Exercise Page



EP 3

Science Literacy Exercise Page
EP 3

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 8–11.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a star diagram in response to the reading.

Standards and Dimensions

NGSS

Disciplinary Core Ideas: ESS1.A: The Universe and Its Stars Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)

PS4.A: Wave Properties A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Connections to the Nature of Science

CCSS

English Language Arts

RST.6-8.4: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

WHST.6-8.6: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

spectrum

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

celestial structure **spectral absorption lines**

wavelength

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

Exercise Page



EP 3

2. Preview the assignment and set expectations.

(MONDAY)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Earth in Space unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
  - *Poems, paintings, and architecture are three ways that people have expressed their fascination with looking at the sky. In the first article, you'll make the connection between the arts and science.*
  - *In the next article, you'll learn how to use a digital SLR camera to make an amazing image of star trails.*
  - *Then, you'll view some images and read quotations that will get you thinking about Earth's place in the universe.*

- *In the fourth article, you'll learn how scientists collect and analyze data from stars to infer their composition.*
- *In the final article, you'll be introduced to five scientists and mathematicians whose discoveries changed space science. By the way, they are all women.*

- Distribute Exercise Page 3. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a star diagram to communicate one new idea you learned from each of the readings in Collection 3.*
- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
How does a celestial structure appear when it is near the horizon compared to when it is not near the horizon?	*It appears bigger near the horizon.*
What does a star trail image look like?	*like concentric circles in the night sky*
What do spectral absorption lines reveal about a star?	*the elements it is made of and its temperature*
What was unusual about the scientists at the Harvard Observatory in the late 1800s?	*Several of them were women.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
How does the sky appear from Earth due to atmosphere scattering light?	*It appears bright in the daytime. Sometimes it is bright blue but can be gray, white, or red and orange at sunrise or sunset.*
What causes stars to appear as trails in the sky?	*As Earth rotates on its axis, the stars seem to rotate, too.*
Which type of telescope described in "Beyond Photography" works similarly to the way rainbows occur? Why?	*the refracting telescope because it has a lens that bends light like sunlight is bent as it passes through a drop of water*

- Refer students to the Exercise Page 3. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to draw a star diagram to communicate something new you learned from each of the five readings.*
  - *Notice that the title of the page has an ellipsis to show that something is left out. Each of the statements you write should also begin with an ellipsis for the same reason. Since the statements you write are completing the sentence, begin with a lowercase letter and end with a period.*
  - *Don't worry about what your classmates are writing. What's new for each person will be different.*
  - *Make sure to put in your own words what you learned, instead of copying text from the reading.*
  - *If you write the statements first and then draw boxes around them, your design may be more effective.*
  - *Color choices are up to you, but you might want to use colors suggested by what you learned.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 3

4. Facilitate discussion.

(Friday)

Facilitate class discussion about the reading collection and writing exercise. The first selection contains the 1806 poem, "The Star." Don't resist the urge to have your class sing all the stanzas to the tune named after the first line in the poem.

Student Reader



Collection 3

Pages 24–37 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Sparking the Imagination"?	*It connects a poem, paintings, and murals to what scientists know about the sky and celestial structures.*
The poem "The Star" was written before 1806. How would you respond to the line "How I wonder what you are!" based on what you learned in this collection?	*Stars seem to rotate in the sky because Earth rotates.* *Telescopes can now be used to figure out what elements a star is made of and how hot one star is as compared to another.* *Visible light is only part of the spectrum of radiation stars give off.*
The Hubble and James Webb space telescopes operate from space. What is a main advantage of a space telescope over a telescope on Earth's surface?	*A space telescope can collect light from stars without the need for the light to pass through Earth's atmosphere, which makes the light wobble and flicker.*
What is the general purpose of the second selection, "Taking a Long Look"?	*It describes a procedure for photographing star trails.*
How does the second selection help you build knowledge on top of what you learned in the first selection?	*The first article shows Van Gogh's painting of the night sky, and the second article points out the similarity of star trails photos to the painting.*
Using the method described, is it possible to capture a star's trail that makes a complete circle? Explain.	*no, because a complete circle would take 24 hours and many of those hours would be during daytime, when the sky is too bright from sunlight to capture starlight*
What is the general purpose of the third article, "Our Pale Blue Dot"?	*I think it may be an attempt to persuade the reader that Earth is a tiny part of the universe.*
How did point of view affect William Anders when he said, "We came all this way to explore the Moon, and the most important thing is that we discovered the Earth"?	*His point of view was from the moon looking back at Earth. This made planet Earth look small and fragile in the darkness of space.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

SUPPORT—Reinforce that Earth's actual distance from the moon does not change during the night. Suggest to students who are not familiar with the moon illusion that, on a clear night, they look for the moon when it is near the horizon and again a few hours later when it is higher above the horizon. They should observe that the moon does look much bigger when it is near objects such as hills, trees, or buildings. To confirm that the illusion is "all in their brain," students can also view the moon through a cardboard tube at the horizon and overhead, thereby eliminating environmental clues.

SUPPORT—Explain to students how rotating the spectral absorption lines image counterclockwise 90 degrees would place it in the middle of most familiar electromagnetic (EM) spectrum diagrams. Have students show on an EM diagram the locations of the wavelengths of light detected by each type of telescope described in the article.

Pages 24–37 Suggested prompts	Sample student responses
How did this selection build on one or more themes from the first selection?	*The quotations have a similar sense of wonder as the poem "The Star."*
What is the general purpose of the fourth article, "Beyond Photography"?	*It describes how scientists use various kinds of telescopes to collect data about stars.*
How do differences in wavelengths relate to what people can see?	*Light that is visible to humans has certain wavelengths, with red light having longer wavelengths than blue light.*
How does the image of the Carina Nebula in this selection relate to Van Gogh's The Starry Night *in the first selection?*	*Both show swirling features.* *Both show light sources of different brightnesses and sizes.*
What is the general purpose of the fifth article, "Out of the Shadows"?	*It identifies some of the women who made important contributions to space science.*
During what span of years were the women profiled born? How would the article be different if it included more profiles of young astronomers working today?	*1857–1943* *If more young astronomers were included, there would probably be a much longer list of women, and they might be more diverse ethnically or racially.*
Three of the five women profiled worked at about the same time in the same place—the Harvard Observatory in Cambridge, Massachusetts. What question could you investigate to find out why?	*What was unusual about the Harvard Observatory related to women astronomers in the late 1800s?*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 3, students should, following a template, draw a star diagram to share one detail from each selection they did not know before reading. Students will need to understand that each numbered point on the star refers to a Collection 3 selection. A sample completed diagram is shown below, but students may cite other examples from the readings.

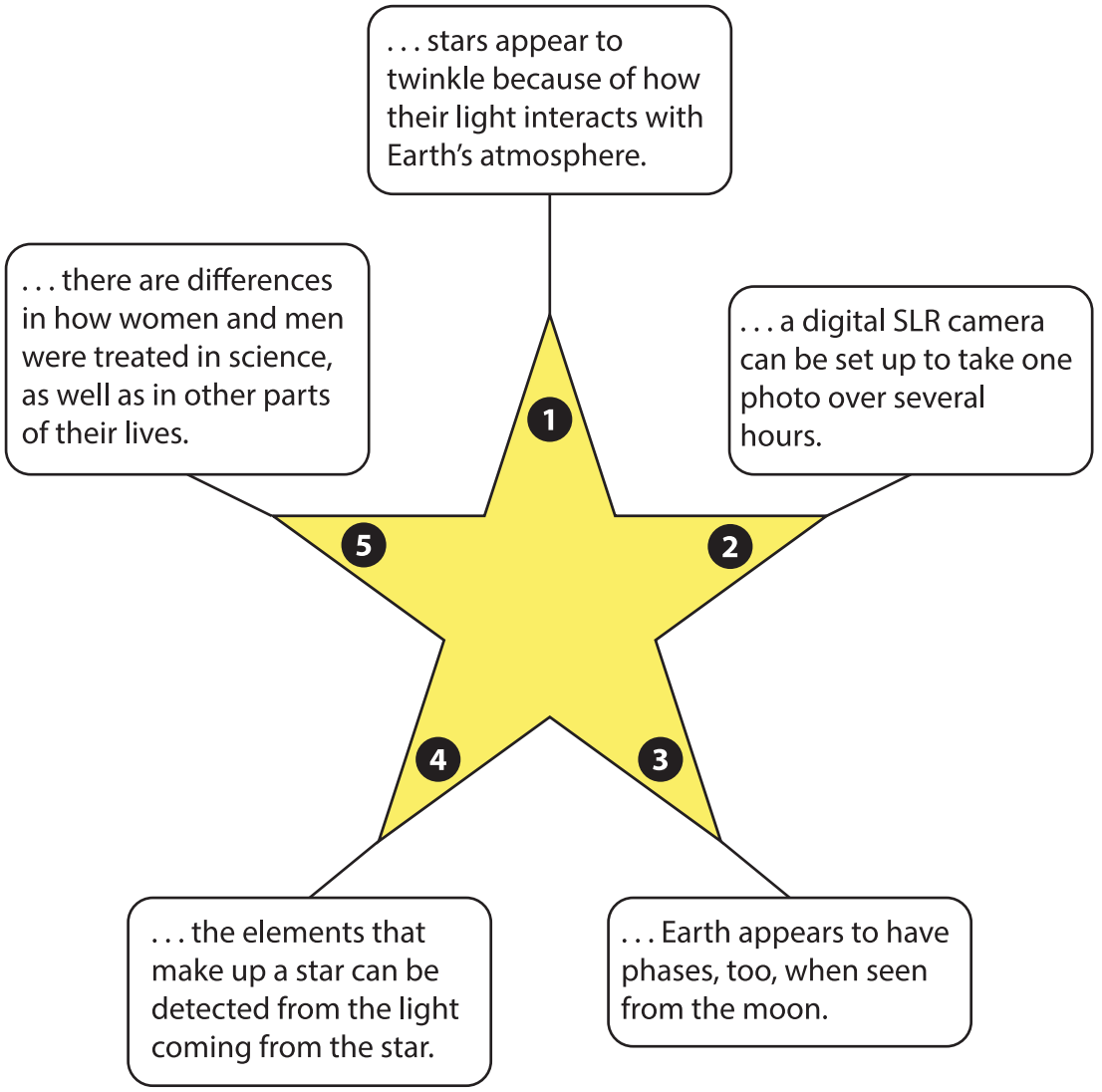
Use the rubric provided on the Exercise Page to supply feedback to each student.

Online Resources



EXTEND—Allow interested students to use a free online graphic organizer tool or app to create their star diagrams. Note that some tools require an email address to get started. Before using with students, preview the tool or app to determine that it conforms to your school's internet use policies.

I didn't know that . . .



LESSON 12

Why does the Moon always change color during a lunar eclipse?

Previous Lesson

We investigated times, places and perspectives needed to see white light split into its many component colors—making a rainbow. We investigated the effect that different materials and their shapes have on (white) light—causing it to change direction (refract) and sometimes make colors and rainbows. We conducted another investigation to recombine colors of light. We discovered that combining light in different ways can change the overall color and brightness of the light that you see.

This Lesson

Putting Pieces Together

2 DAYS



We evaluate models created in earlier lessons before co-constructing a new model that can help us explain why the Moon appears to change color during a lunar eclipse. Then we demonstrate our understanding by preparing for and completing a transfer task.

Next Lesson

We will revisit DQB questions we have not yet addressed and decide to focus on other objects in our solar system. We will gather information from a reading to identify connections and observations others have made about one planet in the solar system (Venus). We will notice additional patterns in other observations of Venus and record new questions about these. We will use a model showing the relative position of motion of Venus and Earth in the system to explain these patterns. We will analyze the scale properties of other planets to look for other patterns.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

12.A Develop and use a model of light in the Earth-Sun-Moon system to describe why the Moon changes color during a lunar eclipse.

12.B Apply science ideas (selective reflection, absorption and transmission of different colors of light by different media and the refraction of light across different media) and evidence to provide an explanation for what causes the apparent color and location of some objects to change under water (effect).

What Students Will Figure Out

- Because they are used under water, where light gets filtered through the water, fish lures are made in specific colors that transmit better through water at different depths so they will be more visible to the eyes of the fish that are living at those depths than other colors would be.
- Fish appear in different positions under water than they actually are to an observer above the water because the light traveling from the fish to the observer's eye travels out of the water and into the air, bending—or refracting—as it travels from one medium (water) into another medium (air).

Lesson 12 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	3 min	**NAVIGATION** We celebrate our new knowledge to help explain lunar eclipses.	A	
2	12 min	**REVISIT MODELS FROM PREVIOUS LESSONS** Evaluate light interaction models from previous lessons and identify which parts and science ideas should move forward, be discarded, or be changed to help explain color changes of the Moon in a lunar eclipse.	B	*Evaluating Past Models*, Classroom consensus models from Lessons 7–11, 5 large sticky notes, Lunar eclipse model revision chart, markers
3	12 min	**CO-CONSTRUCT NEW LUNAR ECLIPSE MODELS IN SMALL GROUPS** Work in small groups to revise a model to explain lunar eclipses by incorporating new evidence.	C	*Evaluating Past Models*, Lunar eclipse model revision chart
4	15 min	**CONSTRUCT CLASS CONSENSUS MODEL OF LUNAR ECLIPSES** Facilitate students in co-constructing a consensus model for how a lunar eclipse can change the apparent color of the Moon.	D-E	*Peer Feedback Guidelines* (optional), *Peer Feedback Self-Assessment* (optional), chart paper, Class consensus model of how can a lunar eclipse can change the apparent color of the Moon chart, markers
				End of day 1
5	7 min	**NAVIGATION: UPDATE PROGRESS TRACKERS** Look back at what we figured out about lunar eclipses to help us look outward at how we can apply our model to a new situation.	F	
6	5 min	**ORIENT TO A RELATED PHENOMENON (FISHING LURE COLORS)** Introduce students to the idea of color change under water and its importance in the fishing industry.	F	Marker caps video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Colors at different depths chart

Part	Duration	Summary	Slide	Materials
7	33 min	**DEMONSTRATE UNDERSTANDING ON AN ASSESSMENT TASK** Students individually demonstrate understanding on an assessment to explain the phenomena of color change and apparent object position under water.	G	*Explaining Fishing Related-Phenomena*, 8.4 Lesson 12 Marker Caps under Water (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

End of day 2

Lesson 12 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Evaluating Past Models* • *Peer Feedback Guidelines* (optional) • *Peer Feedback Self-Assessment* (optional) • *Explaining Fishing Related-Phenomena*		• Classroom consensus models from Lessons 7–11 • 5 large sticky notes • Lunar eclipse model revision chart • markers • chart paper • Class consensus model of how can a lunar eclipse can change the apparent color of the Moon chart • Marker caps video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • Colors at different depths chart

Materials preparation (5 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Ensure that students have quick, visual access to the models (either in their science journals, digitally, or posted publicly in the classroom) from Lessons 7–11.

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Lunar eclipse model revision
- Class consensus model of how a lunar eclipse can change the apparent color of the Moon
- Color change at different depths

Test the video, Marker Caps Under Water 8.4 Lesson 12 Marker Caps Under Water (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). You do not need to play any audio. You might also test the Earthshine podcast 8.4 Lesson 12 NASA Earthshine (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Lesson 12 • Where We Are Going and NOT Going

Where We Are Going

All student ideas generated during Lessons 8–11 will be relevant in this lesson. This lesson is a putting the pieces together lesson where students revise their model of a lunar eclipse. It also includes a summative assessment transfer task about how colors and the positions of objects change under water. A scoring guide is provided for this assessment.

Where We Are NOT Going

Though students use the ideas that different colors of light are selectively absorbed and transmitted by the atmosphere or water, colors of light are not referred to as different wavelengths of light. The wavelength structure of this type of electromagnetic wave is not directly observable nor indirectly derivable in the class of phenomena that students are exploring in this unit. Students will have further opportunities to investigate the electromagnetic spectrum and wave properties in high school.

LEARNING PLAN FOR LESSON 12

1. Navigation

3 MIN

Materials: science notebook

Navigation. Present **slide A**. Ask students to briefly recall what they've figured out recently that could help explain why the Moon looks reddish during a lunar eclipse. Sample student responses

- *The Moon is full during a lunar eclipse.*
- *Earth is entirely surrounded by an atmosphere made of gas, water droplets, ice crystals, and dust particles, which gets less dense the farther up you go.*
- *The more of the atmosphere that light travels through, the more blue light is scattered, which leaves the reddish light to come through.*
- *Sunlight passes through particles in the atmosphere of varying shapes and sizes, which causes differing amounts of scattering and refraction.*
- *Sunlight interacting with matter in the atmosphere also affects its brightness.*
- *When sunlight runs into water droplets in the atmosphere, it bends into different colors—or refracts—as the light enters into the water droplet. These colors then reflect off the back of the water droplet and pass back out into the atmosphere. We see the colors in the sky as a rainbow.*

2. Revisit models from previous lessons.

12 MIN

Materials: science notebook, *Evaluating Past Models*, Classroom consensus models from Lessons 7–11, 5 large sticky notes, Lunar eclipse model revision chart, markers

Revisit models from previous lessons with a partner. Present **slide B** and handout *Evaluating Past Models*. Say, *In an earlier lesson we realized that our models could not explain everything we saw in a lunar eclipse. How can we revise our model for lunar eclipses to also explain the color and brightness changes of the Moon? Work with a partner to look at these prior models and determine what parts, interactions, or ideas we should carry over into a revised model for the lunar eclipse and what parts and science ideas we should discard or change.* Direct students to make note of and refer to the labeled consensus models from Lessons 7–11 on the wall. Give students about 8 minutes to work with a partner to complete *Evaluating Past Models* before leading a discussion to share their thinking.



As students share their thinking, record ideas on a piece of chart paper titled *Lunar eclipse model revision* with a T-chart. Label the left side *Parts, interactions, and science ideas to move forward*. Label the right side *Parts, interactions, and science ideas we might not need*. Use prompts such as the following to guide this idea sharing.

Suggested prompt	Sample student responses
Let's look at Lesson 7 first, where we created a class consensus model that predicted that the Moon would go completely dark due to light from the Sun being blocked by the Earth. What parts, interactions, or ideas should we carry over into a revised model?	*Sometimes the Moon is aligned between the Earth and Sun resulting in the Moon casting a shadow on the Earth. This is what causes a solar eclipse.* *Sometimes the Earth is aligned between the Moon and the Sun, which we thought should result in the Earth casting a shadow on the Moon. This is when a lunar eclipse should occur. The way the objects are lined up is still true, but we also need to show how some of the light gets to the Moon anyway.*

Suggested prompts	Sample student responses
Then in Lesson 8 we got to see that amazing reddish-orange color. So let's look at Lesson 9 next, where we represented the changes in color and brightness that occur in sunlight as it passes through the atmosphere at different times of day. What parts, interactions, or ideas should we carry over into a revised model?	*The color (and brightness) of the Moon and Sun seem to change when those objects are seen near the horizon.* *Sunlight in space (above the Earth's atmosphere) is whiter (and brighter) than sunlight we see through the atmosphere from the surface of Earth.* *Light travels through empty space (even when there is very little or no matter).* *Earth's atmosphere forms a layer of gas, water droplets, ice crystals, and dust particles that gets less dense higher up.* *At sunrise and sunset, the light coming from the Sun passes through the atmosphere at a shallow angle compared to other times of day; when this happens, the light from the Sun takes a longer path to get to you, which means it travels through more of the atmosphere.* *Sunlight dims slightly in brightness and appears yellower, oranger, and then redder the more of Earth's atmosphere it passes through.*
We know from the Unit 6.2: How can containers keep stuff from warming up or cooling down? (Cup Design Unit) and Unit 6.3: Why does a lot of hail, rain, or snow fall at some times and not others? (Storms Unit) that light can be either transmitted, absorbed, or reflected by matter it interacts with … so, how can we describe what we are seeing in terms of these three possible interactions? Let's think first about the light being transmitted. How would we describe what is happening to the light that is transmitted?	*It is becoming oranger or redder and dimmer the more matter it passes through.*
How would we describe what is happening to the light that is scattered or reflected?	*It bounces off the particles in all directions.* *It's the bluish light that gets scattered.*
How would we describe what is happening to the light that's being absorbed?	*Well, we can't see it, so we can't really know.*

Say, *OK,* so *we can't directly see whether some of the light is getting absorbed or not … but let's keep that possibility in mind, too, as we try to figure out why these shifts in color are happening between the light that gets through the atmosphere and the light that leaves it in different directions.*

Suggested prompts	Sample student responses
Let's look at Lesson 10 next, where we showed how white light interacts with a simulated atmosphere so that it becomes redder and dimmer the more that it passes through while the atmosphere itself appears bluish. What parts, interactions, or ideas should we carry over into a revised model?	*When we shine a flashlight through a simulated atmosphere, the original white color becomes oranger or redder the more "atmosphere" it travels through.* *The light gets dimmer the more "atmosphere" it travels through, too.* *We don't need the idea about how we observe a blue color when the white light interacts with the particles in the simulated atmosphere, because the lunar eclipse occurs at night.*
Finally, let's look at Lesson 11, where we showed how the angle or direction of a beam of light changes as it enters and/or exits different types of material. We saw how this direction change (refraction) can cause colors that make up the white light to be separated into the colors of the rainbow. We also saw how overlapping different colors of light results in a new color that is brighter than any of the beams of light before they overlapped. What parts, interactions, and science ideas should we carry over into a revised model?	*When a beam of light enters and/or exits different types of material, the light can change direction (refract).* *I don't think we need the idea that the colors that make up white light can be separated into the colors of the rainbow.* *We don't need the idea that when different colors of light overlap the resulting combination of light is a new color that is brighter than any of the beams of light before they overlapped.*
What if this white light passes through matter that either scatters or absorbs the red colors that make up this white light? What will the light that transmits through that matter end up looking like?	*The light will look dimmer and bluish.*
What if that matter absorbs or scatters the red colors and blue colors? What would the light that transmits through look like then?	*The light will look even dimmer and green.*

Say, *So I hear us saying that the color or colors that transmit through matter from white light could be caused by matter scattering or absorbing other colors. Even if we can't see the absorption happening, it could be affecting what we see being transmitted through. So we could keep the word "absorbed" on our ideas to move forward list.*

3. Co-construct new lunar eclipse models in small groups. 12 MIN

Materials: science notebook, *Evaluating Past Models*, Lunar eclipse model revision chart



Transition to co-construct a revised lunar eclipse model in small groups. Say, *We have a lot of old parts and science ideas we are keeping and new science ideas we are bringing to help revise our lunar eclipse models. So as you work in small groups to revise your models, there is no need to start from scratch. Feel free to annotate over the old Lesson 7 model, redraw it, or use parts of it as you work on revisions.* Keep the *Lunar eclipse model revision* poster up and visible for students to help guide their group's model revision development.*

As groups work on revising their lunar eclipse model, monitor the room and help as needed.

Assessment Opportunity

Building towards: 12.A Develop and use a model of light in the Earth-Sun-Moon system to describe why the Moon changes color during a lunar eclipse.

You can begin assessing this lesson-level performance expectation during this small group modeling activity; you can also listen for what students share or revise in their thinking during the consensus discussion that follows.

What to look/listen for:

- Light from the Sun travels through space in straight lines until it reaches the Earth, the Moon, or both.
- Some of the sunlight striking Earth's surface is reflected back toward space.
- Sunlight hits the half of the Moon that is facing the Sun. This lights up, or illuminates, half of the Moon at all times.
- The light bouncing or reflecting off of the Moon can scatter in many directions. Some of the reflected sunlight travels to the Earth, where the eyes of an observer (or a telescope or camera!) can gather this moonlight. This is how we see the Moon in our sky (except when there is a new Moon!).
- When the orientation of the Earth-Sun-Moon system causes a full Moon, the Earth can block direct sunlight from reaching and reflecting off of the Moon, so we would expect the Moon to go dark. However, it stays lit and turns a reddish color, which means light is somehow getting to its surface:
  - White light passing through the Earth's atmosphere bends (refracts) or changes direction by the gasses (including water vapor) and other particles in the atmosphere so that some of the light reaches the Moon.
  - Less light than normal (but still more light than none) reaches the Moon's surface after passing through the atmosphere and reflects back to Earth so we can see the Moon.
  - As this happens, the bluer light that makes up the white sunlight gets scattered disproportionately (more than red) in the atmosphere.
  - More of the redder light that made up the white sunlight passes through the atmosphere. This is the light that reaches the Moon's surface and reflects off of it to Earth so the Moon looks reddish.
  - The red light is what gets through the atmosphere best, and then that red light is also bent by the atmosphere so it shines on the Moon.

*** Supporting Students in Engaging in Developing and Using Models**

Remind students here about the nature of science: Scientific explanations are subject to revision and improvement in light of new evidence. Connect back to what they learned in previous lessons about the parts, interactions, and science ideas that help explain lunar eclipses. As we have investigated and identified new evidence to explain different phenomena associated with lunar eclipses, our explanations are changing based on that new evidence.

What to do: If students are having trouble explaining the changes during a lunar eclipse, remind them that they can refer back to the investigation notes they have in their notebooks. They can consider which parts of the systems they investigated are similar or different from the lunar eclipse and what they represent. If students are struggling to represent ideas such as the changes in light as it moves through the system, encourage them to use the resources gathered in their Progress Trackers.

4. Construct Class Consensus Model of lunar eclipses.

15 MIN

Materials: science notebook, *Peer Feedback Guidelines* (optional), *Peer Feedback Self-Assessment* (optional), chart paper, Class consensus model of how can a lunar eclipse can change the apparent color of the Moon chart, markers

Share small group models in a Scientists Circle. Present **slide D** and have the class move into a Scientists Circle to share their small group models. Say, *As each group presents their models, have students record in their science notebook the similarities, differences, and information in their models you think we should include in our class consensus model.* Have each group present their models. Once the groups have finished sharing, use the prompts below to lead a discussion.

- What similarities did the group models have?
- What differences did the group models have?
- What information from the group models should we be sure to include in our class consensus model?

Consider recording student responses on a piece of chart paper. If time permits, you can have students use *Peer Feedback Guidelines* to provide feedback on each other's models before bringing them together for the classroom consensus model. If you choose to do this, make sure to give enough time for groups to return to and revise their model (before moving on) and then you can have students reflect on how well they gave and received feedback, using *Peer Feedback Self-Assessment*.

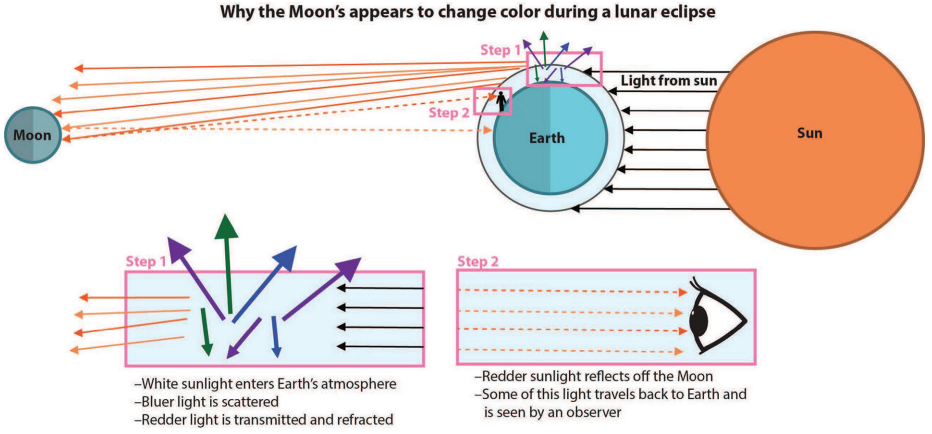
Develop a class consensus model of lunar eclipses. Present **slide E** and ask, *What information should we add to our prior model to reflect our new understanding and honor our group models?* See the Key Ideas box below for examples of what to listen for from students.

Key Ideas

Purpose of this discussion: Take stock of all the ideas gathered in Lessons 7–11 to come to consensus on why lunar eclipses appear redder and do not just go dark.

Listen for these ideas: See the "what to listen for" in the assessment guidance callout in the previous part.

Post the chart paper (from Lesson 7) labeled *Class consensus model of lunar eclipse* and use a different colored marker to annotate the priorly developed model as directed by the class. A sample of the revised class consensus model developed in this lesson is pictured below.



Additional Guidance

Earthshine (the glow caused by sunlight reflected off the Earth, especially on the darker portion of a crescent Moon) plays a small role in lighting the Moon on most nights but almost has no contribution to why we can see the Moon during a lunar eclipse. Because of this, earthshine is not needed to explain the lunar eclipse phenomenon. If students are interested in more information, share 8.4 Lesson 12 NASA Earthshine (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) .

End of day 1

5. Navigation: update Progress Trackers.

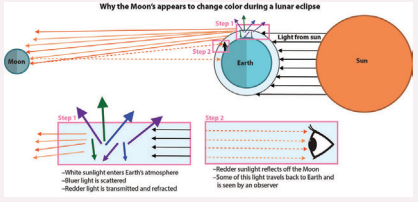
7 MIN

Materials: science notebook

Update Progress Trackers to reflect new understandings. Present **slide F** and ask, *Looking back, what did we accomplish and figure out last time? Let's take a few minutes to process this on your own in your Progress Trackers.*

A list of possible student responses are shown below. Do not expect that your students will include all of these ideas in their trackers.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
Why does the Moon always change color during a lunar eclipse?	• Light from the Sun travels through space in straight lines until it reaches the Earth, the Moon, or both. • Some of the sunlight striking Earth's surface is reflected back toward space. • Sunlight hits the half of the Moon that is facing the Sun. This lights up, or illuminates, half of the Moon at all times. • The light bouncing or reflecting off of the Moon can scatter in many directions. Some of the reflected sunlight travels to the Earth, where the eyes of an observer (or a telescope or camera!) can gather this moonlight. This is how we see the Moon in our sky (except when there is a new Moon!). • When the orientation of the Earth-Sun-Moon system causes a full Moon, the Earth can block direct sunlight from reaching and reflecting off of the Moon, so we would expect the Moon to go dark. However, it stays lit and turns a reddish color, which means light is somehow getting to its surface: ◦ White light passing through the Earth's atmosphere bends (refracts) or changes direction by the gasses (including water vapor) and other particles in the atmosphere so that some of the light reaches the Moon. ◦ Less light than normal (but still more light than none) reaches the Moon's surface after passing through the atmosphere and reflects back to Earth so we can see the Moon.	Answers will vary, but some sample ideas could include the following: • For some people or cultures, the apparent color change in the Moon is a bad omen or could be scary if you didn't know when or why it was happening. • Some cultures celebrate the apparent change in the Moon's color.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
Why does the Moon always change color during a lunar eclipse?	◦ As this happens, the bluer light that makes up the white sunlight gets scattered disproportionately (more than red) in the atmosphere. ◦ More of the redder light that made up the white sunlight passes through the atmosphere. This is the light that reaches the Moon's surface and reflects off of it to Earth so the Moon looks reddish. ◦ The red light is what gets through the atmosphere best, and then that red light is also bent by the atmosphere so it shines on the Moon. 	Answers will vary, but some sample ideas could include the following: • For some people or cultures, the apparent color change in the Moon is a bad omen or could be scary if you didn't know when or why it was happening. • Some cultures celebrate the apparent change in the Moon's color.

Use the Progress Tracker to look outward. *Say, our model yesterday was definitely more complete, but any powerful model in science can explain more than just one or few phenomena. Let's see how far we can push this model to explain other phenomena or what other things we can explain with this model. Let's explore some related phenomena where light from the Sun is traveling through different stuff so that we might be able to explain and think about if and how we might apply this model to explain what we see.*

6. Orient to a related phenomenon (fishing lure colors). 5 MIN

Materials: 8.4 Lesson 12 Marker Caps under Water (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), Colors at different depths chart

Explain the fish lure color phenomenon. Display **slide F.** Tell students, *OK. Are you ready to apply what we've figured out in a new context? Let's go for it! I have a really interesting thing to share with you. Before I do, I want to share some background knowledge and a video with you so you have more context.*

Distribute *Explaining Fishing Related-Phenomena*. Explain that people all over the world fish for food, for their jobs, and for other things, like recreation. Read the first paragraph on *Explaining Fishing Related-Phenomena* outloud to the class or have small groups read it outloud to each other. Have students make a prediction (on page 1). Before showing the video, point out that there are a lot of colors in the fishing lures image. Say, *One way to see how a fish sees under water is to use objects of different colors and put them under water. Different colored marker caps were put under water and filmed so we could see what a fish sees under water. Let's watch this video so you can see if your predictions are correct.*

Create a whole class Notice chart for Marker Caps Under Water, and then play at 8.4 Lesson 12 Marker Caps under Water once without stopping or recording anything. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) After playing the video once, give students a chance to share any noticings and then a chance to ask any questions about what is going on in the video. Record the noticings on chart paper labeled *Colors at different depths*. Watch the video again, but this time after the video, fill out page 2 as a class.

Explain that students are now going to take an individual assessment around the marker color-fish lure phenomena. Tell them they will need to decide which parts they need to keep and use, which science ideas they need to keep and use, and think, is there any part of this they can't explain using our current evidence or our current model?

Help students prepare for *Explaining Fishing Related-Phenomena* by having them locate their Progress Trackers and *Evaluating Past Models* from the previous class in their science notebooks.

7. Demonstrate understanding on an assessment task. 33 MIN

Materials: *Explaining Fishing Related-Phenomena*, 8.4 Lesson 12 Marker Caps under Water (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Monitor students as they work on *Explaining Fishing Related-Phenomena* individually. Display **slide G.** This will take students most of a class period to complete.*



Assessment Opportunity

Building towards: 12.B Apply science ideas (selective reflection, absorption, and transmission of different colors of light by different media and the refraction of light across different media) and evidence to provide an explanation for what causes the apparent color and location of some objects to change under water (effect).

What to look/ listen for: See scoring guidance on *Explaining Fishing-Related Phenomena*.

*** Attending to Equity**
Universal Design for Learning: If your students are struggling, consider supporting their *action and expression* in creating the model by having them use their Progress Trackers and *Evaluating Past Models* for this assessment task.

This assessment encourages students to demonstrate their understanding of key skills and concepts from the unit so

What to do: If students are having trouble getting started, ask, *What do you think is happening in this investigation? What does this data show us about light and color? What are some things we have done in class that could help you figure this out?* You may also want to create a word bank for students to use with the key terms from Lessons 8–11 or refer students to the Word Wall. Also, have students revisit the Lunar Eclipse Model Revision poster to make connections between our science ideas and the assessment questions.*

Say, Thanks for all of your deep thinking today. Let's start next time by not only celebrating what we have figured out but also seeing in what clusters on our DQB we still have unanswered questions.

far through multiple different modalities, including drawing models. Some students may benefit from using multiple modalities to show their thinking for any or all of the questions on this assessment. You may consider allowing some students to present their answers verbally with you or another student acting as a scribe to record their thinking on paper. Other students may benefit from using gestures rather than images to describe parts of their models. Some students might also benefit from using manipulatives to represent parts of the model and to support a written or verbal explanation of what's happening in each part of the model. In each case, encouraging students to use multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to demonstrate proficiency.

LESSON 13

What new patterns do we see when we look more closely at other objects in the sky?

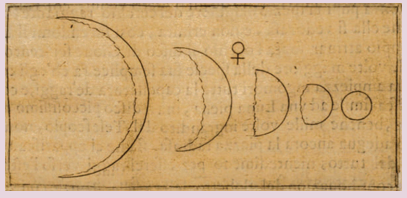
Previous Lesson

We evaluated models created in those lessons before we co-constructed a new model of what is happening during a lunar eclipse. We prepared for and completed a transfer task.

This Lesson

Investigation

3 DAYS



Galileo Galilei - Public Domain, Annotation Fernando de Gorocica CC BY SA-3.0

We revisited DQB questions we have not yet addressed and decided to focus on other objects in our solar system. We gather information from a reading to identify connections and observations others have made about one planet in the solar system (Venus). We notice additional patterns in other observations of Venus and record new questions about these. We use a model showing the relative position of motion of Venus and Earth in the system to explain these patterns. We analyze the scale properties of other planets to look for other patterns.

Next Lesson

We will share initial ideas about patterns of motion in the solar system, which will lead us to conduct a cause-and-effect thought experiment. We will use a simulation to investigate how changing distance and size affects an object's orbit around another object in the solar system. We will build understanding as a class about the relationship between size, distance, and the strength of the force of gravity.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

13.A Read an article and use it to determine some observations people have made of one planet (Venus) in the past, the patterns they noticed over time, and different connections that different cultures have made to Venus.

13.B Construct an explanation of the patterns in the apparent size and shape (scale properties) of Venus from Earth as it orbits the Sun.

13.C Analyze and interpret data to identify patterns in and between different scale properties for planets and some of their moons in our solar system (including relative size, orbital distance from the Sun, surface features, if any, and atmosphere).

What Students Will Figure Out

- Even though Venus and other planets in the sky look like stars, they move differently and their position changes.
- Planets closer to the Sun are rocky and small, and objects farther out are large and gaseous.
- All solar system objects orbit the Sun in the same direction (counterclockwise if looking down on Earth's Northern Hemisphere from above it).
- There are nested patterns of orbits, but smaller objects tend to orbit larger objects.
- Most objects are orbiting the solar system on a similar plane.

Lesson 13 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Refer back to class explanations of light phenomena and take stock of the Driving Question Board.	A-C	Driving Question Board
2	8 min	**OBSERVE PLANETS IN THE NIGHT SKY AND MAKE CONNECTIONS** Observe annotated images of some bright planets visible in the night sky from Earth and reflect on our and others' connections to planets.	D-F	*Experiences and Connections with the Planets,* Driving Question Board
3	10 min	**OBTAIN INFORMATION ABOUT CULTURAL CONNECTIONS TO THE PLANETS** Read individually about a variety of cultural connections to planets.	G-I	*Venus in Cultures from Around the World,* highlighter
4	12 min	**IDENTIFY PARTS OF THE SYSTEM NEEDED TO EXPLAIN PATTERNS IN VENUS'S POSITION IN NIGHT SKY** Establish the parts needed to develop a model to explain observations of Venus. Develop initial models of the Earth-Sun-Venus system to explain Venus's changing appearance.	J-K	chart paper labeled "Why is Venus seen where it is in the night sky and sometimes not seen at all?", markers
5	5 min	**IDENTIFY ADDITIONAL TOOLS FOR OBSERVING OBJECTS IN THE SKY AND MAKE PREDICTIONS** Brainstorm a list of additional tools to help people observe objects in the night sky. Make predictions about what types of information those tools would help us learn about Venus.	L-M	*L13: Community Guide for Looking at the Sky,* chart paper labeled "Why is Venus seen where it is in the night sky and sometimes not seen at all?", markers

End of day 1

Part	Duration	Summary	Slide	Materials
6	6 min	**NOTICE AND WONDER** Record notice and wonderings around the first recorded drawings of what Venus looked like through a telescope.	N	*L13: Community Guide for Looking at the Sky*
7	8 min	**SHARE NOTICINGS AND WONDERING ABOUT VENUS AND MAKE PREDICTIONS** Share noticing and wonderings around drawings of Venus made from observing through the first telescope and from modern photographs of Venus taken through a telescope. Make predictions about whether it might be involved in something similar to a lunar or solar eclipse.	O-R	Lesson 7 class consensus models "How does a solar eclipse happen?", "Why don't we see a solar eclipse with every New Moon?", "How often might we see a solar eclipse?"
8	5 min	**ANALYZE A VIDEO OF A TRANSIT OF VENUS** Observe a timelapse video of a transit of Venus from June 5, 2012. Compare the frequency of this phenomena to a lunar eclipse.	S-T	8.4 Lesson 13 Transit of Venus (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper to add the co-constructed transit definition to the Word Wall
9	13 min	**USE A MODEL TO EXPLAIN VENUS-RELATED PATTERNS** Evaluate two models showing the Earth-Sun-Venus system by creating models with manipulatives to explain Venus-related patterns.	U-V	*Key: Explaining Venus-Related Patterns*
10	7 min	**RECORD AND DISCUSS PREDICTIONS FOR OTHER PLANETS** Use patterns in the motion of Venus to make predictions about the placement of Mercury, Mars, and Jupiter in the solar system.	W-X	chart paper, markers, chart paper to add the coconstructed solar system definition to the Word Wall
11	6 min	**NAVIGATE** Predict what we might see on planets when we use more powerful telescopes and orient to additional technologies. Identify what types of data about other planets would be helpful to collect.	Y-CC	

End of day 2

Part	Duration	Summary	Slide	Materials
12	3 min	**IDENTIFY OTHER TYPES OF DATA TO COLLECT** Share examples of other types of data we would want to collect with equipment sent to other objects in the solar system.	DD	
13	20 min	**ANALYZE AND INTERPRET DATA FROM INFOGRAPHICS** Analyze and interpret data from infographics about different solar system objects.	EE-GG	*Looking for Patterns in the Solar System Infographics, Analyzing and Interpreting Data from Infographics Close Reading Protocol*
14	10 min	**IDENTIFY MORE PATTERNS BETWEEN SOLAR SYSTEM OBJECTS** Use an online interactive to simulate touring the solar system to identify patterns about the characteristics of objects in the solar system.	HH	(See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) 8.4 Lesson 13 NASA Eyes on the Solar System Tour (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
15	12 min	**UPDATE PROGRESS TRACKERS AND NAVIGATION** Summarize key observations and patterns through wonderings in individual Progress Trackers. Navigate to the next lesson.	II-JJ	
				End of day 3
		SCIENCE LITERACY ROUTINE Upon completion of Lesson 13, students are ready to read Student Reader Collection 4 and then respond to the writing exercise.		Student Reader Collection 4: *Space On-Screen*

Lesson 13 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Experiences and Connections with the Planets* • *Venus in Cultures from Around the World* • highlighter • *L13: Community Guide for Looking at the Sky* • *Looking for Patterns in the Solar System Infographics* • *Analyzing and Interpreting Data from Infographics Close Reading Protocol*		• Driving Question Board • chart paper labeled "Why is Venus seen where it is in the night sky and sometimes not seen at all?" • markers • Lesson 7 class consensus models "How does a solar eclipse happen?" • "Why don't we see a solar eclipse with every New Moon?" • "How often might we see a solar eclipse?" • 8.4 Lesson 13 Transit of Venus (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper to add the co-constructed transit definition to the Word Wall • *Key: Explaining Venus-Related Patterns* • chart paper • chart paper to add the co-constructed solar system definition to the Word Wall • NASA's Eyes Website (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • 8.4 Lesson 13 NASA Eyes on the Solar System Tour (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (15 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Reminder about supporting students with visual disabilities: This unit uses images as data. Specifically in this lesson, students analyze images of changes in planet position and shape, as well as watch videos of planet motion. Students who are color blind or have low vision will usually be able to identify that light is changing as Venus passes in front of the Sun and identify where in the sky the planet is. However, students with monochromacy/achromatopsia will likely not be able to recognise the color change. So, you will need to make accommodations so that students with this and

other visual disabilities can access this data. Depending on your students' needs, suggested modifications include enlarging and/or brightening the provided digital versions of these photos or using alternate text descriptions.

Test these videos and simulations: NASA Transit of Venus at 8.4 Lesson 13 Transit of Venus (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), NASA Eyes on the Solar System at (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), and NASA Eyes on the Solar System Tour at 8.4 Lesson 13 NASA Eyes on the Solar System Tour (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Prepare chart paper for this poster:

- Patterns in Observing Venus

Be sure you have materials ready to add the following words to the Word Wall: *transit* and *solar system.* Do not post these on the Wall until after your class has developed a shared understanding of their meanings.

Optional: Create typed up copies of the DQB on paper or digitally for students to mark up or reference in the first half of day 1.

Pull together sets of the manipulatives from Lessons 2 and 3 (e.g., foam spheres and light sources) for student groups to use if they request them for related explanation and modeling activity on day 2 of this lesson.

Lesson 13 • Where We Are Going and NOT Going

Where We Are Going

This lesson marks a turn in the unit where students are asked to view patterns and phenomena connected to the space and sky with more than just their unaided eyes. It represents coming off of Earth and going farther into the solar system, moving beyond the Sun and Moon, as was the larger focus in prior lessons. This lesson provides motivation for building out gravity as the mechanism behind orbiting objects in space but asking students to begin to notice patterns about how the solar system is organized.

Where We Are NOT Going

This lesson does not venture farther out into space to include exoplanets and their star systems. This will be done in later lessons as students co-construct a model for solar system and galaxy formation, and beyond.

The clarification statement for MS-ESS1-3 in the NGSS specifies that students will not need to recall facts about properties of the planets and other solar system bodies. Nor are they required to memorize the names of the planets in the solar system or their order.

LEARNING PLAN FOR LESSON 13

1. Navigation

10 MIN

Materials: science notebook, Driving Question Board

Celebrate new knowledge. Say, *We were able to explain many common phenomena involving light and color that we had questions about, like sunsets and sunrises, rainbows, the redder Moon observed during a lunar eclipse, and even color changes underwater. We accomplished this together as a class, and we should celebrate our newfound understanding.* As appropriate, briefly refer to class models or individual student work from the previous lesson set.

Take stock of the Driving Question Board. Present **slide A.** Have students record the related T-chart in their notebooks. Find a way to provide students with access to review the Driving Question Board. This could be done by sending students in groups to the board to analyze the DQB or distributing typed up copies of the DQB on paper or digitally. Ask students to record examples of questions that have and have not been addressed.

Additional Guidance

As described in the teacher preparation notes, prepare for this activity by taking note of Driving Question Board questions that have been answered related to

- light phenomena;
- phenomena involving the Earth-Sun-Moon system;
- phenomena related to the solar system beyond the Earth-Sun-Moon system; and
- phenomena related to objects beyond the solar system.

Come to an agreement as a class about which types of questions and phenomena the class has already investigated and/or answered. Present **slide B.** Ask students, *What groups of questions on our DQB have we investigated or answered?* Look for students to identify groups of questions that relate to atmospheric light phenomena, seasons, the movement of the Sun and Moon in the sky, Moon phases, or eclipses.

Then ask, *What evidence do you have to support your idea?* Look for students to point back to specific lessons or investigations where they figured out answers to some of the DQB questions.

Come to agreement as a class about which types of questions and phenomena present on the Driving Question Board that the class has not yet investigated. Note a few questions that many students have classified as having not been addressed that relate to planetary phenomena or other objects besides the Sun, Moon, or stars.

Prepare to look at images of planets. Present **slide C.** Say, *There are many ways we can classify or group our questions and related phenomena that we have not already addressed. When people began to consider the patterns of these other objects in the sky that they could see, all of those objects appeared to us on Earth to be much smaller than either the Sun or the Moon. That makes it harder to figure out what those objects were and where they were located in the larger system. As people studied these other objects, some of their patterns of motion seemed more complex than those of the Sun or Moon.*

Many of these objects we now refer to as planets. Lets take a look at some images of the sky that show some of the most easily observable planets that can be seen at certain times of the year to become more familiar with the patterns that people noticed in them over time.

2. Observe planets in the night sky and make connections.

8 MIN

Materials: science notebook, *Experiences and Connections with the Planets,* Driving Question Board

Show an image of planets in the night sky. Display **slide D**, feeling free to move between the two slides. Say, *This is how some planets looked to someone at {location} on {date and time}.* See guidance below on how to localize the image on **slide D** for your context.

Additional Guidance

The image on **slide D** is a representation of the night sky in May 2021 from Chicago, Illinois, taken from www.stellarium.org. You may choose to replace this with an image or images of the annotated planets in the night sky at a different time and location, for example, near your school and around the time you are teaching this lesson. You do not need to find an image with all of the planets in the night sky, but try to capture one with at least two planets.

Note that depending on when you are teaching the lesson, various planets may not be visible in the night sky and you may need to choose a different time. Consider reviewing monthly planet watching guides (for example, from EarthSky.org or timeanddate.com). This information may also be used to supplement *L13: Community Guide for Looking at the Sky,* the night sky activity given as optional home learning at the end of this day.

Reflect on our experiences with observing planets and other connections and add questions to the Driving Question Board. Display **slide E**. Say, *We have spent a lot of time thinking about how objects in the sky impact our daily lives. Remember back to the podcasts from Lesson 1 that planets visible in the night sky also impacted people's daily lives.* Handout *Experiences and Connections with the Planets* and have students individually answer one or more questions on the table on *Experiences and Connections with the Planets* for about 4 minutes. Then display **slide F** have students discuss their answers with partners for an additional 4 minutes, recording new questions they have about the planets. Invite students to add new questions to the Driving Question Board.*

*** Attending to Equity**

Students will have varying levels of experience and connections with observing planets. Note that students are not expected to answer all three questions in the table. If students are struggling to recall experiences or make connections, you may point them to the third question around connections other communities have made to the planets. In the Lesson 1 podcasts, Annette Lee, Thebe Medupe, and Gerardo Aldana all made reference to planets. Students may be familiar with other cultural connections people have made and continue to make to planets. Students may have also observed or noted planets when documenting sky patterns in Lesson 1. Note also that optional Home Learning at the end of this day will give students another opportunity to use the *L13: Community Guide for Looking at the Sky* to observe planets.

3. Obtain information about cultural connections to the planets. 10 MIN

Materials: *Venus in Cultures from Around the World,* highlighter

Recall ways we uncovered patterns and connections people have made related to the Sun, Moon, and stars. Display **slide G**.

Suggested prompts	Sample student responses
Early in our work with figuring out the patterns people have observed for the Sun, Moon, and stars and the connections they made to them, we decided we needed more data. What were some sources of data we used to figure out what patterns there were and what connections people made to them?	*We interviewed our trusted community members.* *We listened to the stories of people around the world.* *We examined artifacts and images of the phenomena in the stories.* *We used physical models and online interactives to simulate what was happening in the different systems.*
Can someone share with the class some of these connections we uncovered?	*Many of us love sunrises and sunsets! We notice diffraction of light in many situations.* *The colors of sunrises and sunsets, rainbows, and other atmospheric color phenomena have long been important to visual artists, poets, and regular people across time and cultures.* *Patterns in how energy from the Sun is experienced in different places on Earth and at different times of year impact culture.* *We notice, observe and recognize the lunar phases and changes in the Sun's path across the sky in our lived experiences.* *Astronomical events like solstices, eclipses, Manhattanhenge, and others have been anticipated and observed with fascination by cultures around the world for millennia.*

Note the power of these phenomena to influence people in the deep past, today, and in the future. Explain that by reflecting on the connections the class and other people have made to these phenomena, people have been connected to and used a variety of tools and lenses to make sense of these phenomena through time and cultures. Note that this is just as true for observations related to planets as it was for the other objects we've investigated, like the Sun, Moon, and stars.

Complete short reading and annotate it for cultural connections that people have made to Venus over time and observations they made. Display **slide H.** Say, *Let's dive deeper into some connections people around the world have made into one planet, in particular, that you mentioned earlier. That planet is Venus.* Distribute *Venus in Cultures from Around the World* and ask students to complete a short reading around Mayan, Indian, Greek, Roman, Egyptian, and Norse observations of Venus, annotating the reading with cultural connections (underline) and observations about Venus that we could investigate today (highlight).



Assessment Opportunity

Building towards: 13.A Read an article and use it to determine some observations people have made of one planet (Venus) in the past, the patterns they noticed over time, and different connections that different cultures have made to Venus.

What to look/listen for:

- Identifying Venus as appearing to the 3rd brightest object in the sky, that changes in brightness over time (multiple days).
- Identifying Venus as appearing in different portions of the sky (day/night) at different points in time.
- Identifying cultural connections such as associations with a god and/or timing important events, days of the week, or influencing life on Earth.

What to do: See the two related alternate guidance boxes for other ideas on how to support students with either the reading in class or sharing the reading with trusted members of their community and how to gather additional information from that context.

Alternate Activity

If you have a bit more time for this part of the lesson and you think your students would benefit from a more structured activity to support this reading, assign students roles for independent reading and small group discussion. Before reading, assign students the following roles in approximately equal numbers:

- *Crosscutting Concepts Finder:* Given a list of crosscutting concepts, identify one or two that are related to this text and be ready to tell how/why.
- *Visualizes:* What are the most important images in your mind from this text? Why? What details in the text helped you picture those images?
- *Summarizes:* What are the key ideas from this text? How can you briefly retell or rephrase those ideas? How did you know those were the key ideas?
- *Questioner:* What are you wondering about this text? What questions do you have for the author or the people described in this text?

After reading, group students so each group has one person with each role, and have them discuss their thinking, sharing ideas and asking questions based on the role they have.

Alternate Activity

If students struggle to identify some of these connections in the reading, encourage them to share the reading with a trusted community member outside of class and document what connections or questions the reading raised for the person they shared it with. You could also provide a copy of *L13: Community Guide for Looking at the Sky* for these students to use as a tool to help support students and trusted members of their community in observing specific patterns in the sky. Encourage students to bring those observations and ideas back to class to inform and enrich upcoming work in the classroom. Inviting students to bring their family and/or community knowledge, experiences, and practices into school not only supports students in coordinating the learning they do outside school with what they do in school but can also help you as a teacher to expand your understanding of the strengths of the families and communities you work with.

Do not require that students complete this home learning and do not score it; the goal of this guide is to promote conversation between students and others in their family and/or community about what they're doing in class and to expand students' exploration of patterns in the sky by bringing in those ideas.

If you feel it is not safe or practical for students to be outside of their homes, especially at night, encourage students to look out a window or have them do the activity at school. Also, make sure to reiterate with your students to never stare directly at the Sun because it can be permanently damaging to their eyes.

Highlight some patterns around Venus that all three cultures noticed and could predict. Give students 1 minute to share with a partner what they noticed about cultural connections to Venus from their readings (ideas they underlined). Then ask students to share with the class observations or patterns that were noted in the readings (ideas they highlighted). If time permits, make a quick list on the board or chart paper of some of these patterns, labeling it "Patterns in Observing Venus".

Look for students to identify some of the following:

- Venus is the third brightest natural object in the night sky after the Sun and the Moon, though its brightness varies in predictable patterns.
- Planets do not follow the same patterns of stars in the night sky.
- Venus is observed in a cyclic pattern:
    - Venus can be seen in the morning sky for about 263 days. It is visible in the eastern sky just before and as the Sun rises.
    - Next, Venus is not visible in the night sky for about 50 days.
    - Next, Venus can be seen in the evening sky for about 263 days. It is visible in the western sky just after and as the Sun is setting.
    - Next, Venus is not visible in the night sky for about 8 days.
    - Next, the previous four steps repeat, over and over again.

Show images of Venus at sunrise and sunset in the sky. Display **slide I.** Give students a minute to study the images in these slides and summarize again the repeating pattern that people noticed in whether Venus is visible in the morning sky, not visible, or visible in the evening sky.

4. Identify parts of the system needed to explain patterns in Venus's position in night sky. 12 MIN

Materials: science notebook, chart paper labeled "Why is Venus seen where it is in the night sky and sometimes not seen at all?", markers

Establish the parts needed in a model that can explain observations of Venus. Say, *We've done some thinking about how we used models of the Earth-Sun-Moon system to explain the path of the Sun across the sky, Moon phases, and eclipses. Those models include the Earth, a person on Earth, the Sun, sunlight (or light rays), and the Moon as well as their positions and motion compared to one another. Which of these parts and interactions do we think we would need to include in a model that explains the pattern of observations of Venus in the night sky?*

Display **slide J.** Give students 2 minutes to discuss the prompts on the slide. Then ask students to share out. Anticipated responses include the Earth, a person on Earth, the Sun, sunlight or light rays, and Venus. Some students may also suggest that we may need to have one or more of the following: (a) the Earth moving (rotating once a day); (b) Earth moving through a circular orbit around the Sun over the course of the years; and/or (c) Venus moving (possibly in an orbit).

Additional Guidance

Students may wonder about the source of light that allows us to observe Venus. If a student raises this question about the source of light that allows us to see Venus, clarify student reasoning by referring to the Moon, an object that we know does not produce its own light (that we observe due to reflected sunlight), and the Sun as an object that does produce its own light. Note that whichever the case is for Venus, how it interacts with light will be something we need to account for in our model.

Additional Guidance

Some students may suggest that Venus is an inner planet, with an orbit around the Sun interior to Earth's orbit. If a student suggests this, ask another student to explain this proposed orientation of the Sun, Venus, and Earth (which many students may have prior knowledge about) again to the whole class.

Develop initial models of the Earth-Sun-Venus system. Display **slide K.** Have students develop an initial model of the Earth-Sun-Venus system to show the relationships between them that help explain the patterns of Venus in the sky in their science notebooks. As students create their initial models, walk around the room and choose two or three different model ideas to highlight during a class discussion. Bring the two or three different models up to the front of the room so the class can see them.

Suggested prompt	Sample student responses
What differences do these models have?	*One shows the Sun, then Earth, then Venus, and the other shows the Sun, then Venus, then Earth.* *Venus is orbiting Earth and not the Sun.*

Suggested prompt	Sample student responses
What types of information would help us determine which model is accurate?	*pictures from space* *simulations of their orbits* *how far away Venus is from the Sun*

5. Identify additional tools for observing objects in the sky and make predictions. 5 MIN

Materials: *L13: Community Guide for Looking at the Sky,* chart paper labeled "Why is Venus seen where it is in the night sky and sometimes not seen at all?", markers

Identify technologies/devices for seeing distant objects in more detail. Say, *We have a lot of different ideas about how the Earth-Sun-Venus system interacts to cause us to notice changes in Venus's appearance. People a long time ago also had a lot of different ideas. These disagreements led people to want to figure out ways to gather more data to support their ideas. A little over 400 years ago, people started figuring out ways to create new kinds of devices that allowed them to magnify far away objects so they could see them in more detail and more clearly. This allowed them to discover even more patterns.* Display **slide L**. Read the prompt and give a moment for students to consider examples of technologies or devices you know of that help people see objects that are far away in greater detail than they can with the unaided eyes. Anticipated responses may include: *telescopes, binoculars, glasses, digital cameras, magnifying lenses or lenses in general, satellites, and spacecraft.*

Make predictions. Display **slide M**. Have students turn and talk with a partner about the prompt, *What sorts of things do you think people might see when looking at Venus when using a telescope that they couldn't see with their unaided eyes?* Give students about 2 minutes to discuss their predictions with a partner. If you have time, ask for a few volunteers to share their predictions. Say, *Next time, we will look at some images of Venus that people have made using telescopes.*

Collect student annotated copies of *Venus in Cultures from Around the World* before the end of the period. Handout *L13: Community Guide for Looking at the Sky* as home learning.

Additional Guidance

L13: Community Guide for Looking at the Sky is a tool that has been used in several lessons to help support students and trusted members of their community in observing specific patterns in the sky. Encourage students to bring those observations and ideas back to class to inform and enrich upcoming work in the classroom. Inviting students to bring their family and/or community knowledge, experiences, and practices into school not only supports students in coordinating the learning they do outside school with what they do in school but can also help you as a teacher to expand your understanding of the strengths of the families and communities you work with. Do not require that students complete this home learning and do not score it; the goal of this guide is to promote conversation between students and others in their family and/or community about what they're doing in class and to expand students' exploration of patterns in the sky by bringing in those ideas.

End of day 1

6. Notice and wonder.

6 MIN

Materials: science notebook, *L13: Community Guide for Looking at the Sky*

Revisit home learning. Ask for a few volunteers to share what they wrote down on *L13: Community Guide for Looking at the Sky*. Accept all responses.

Frame where and when the next set of images are from. Remind students that we were left with questions and made some predictions about what we would see on Venus using telescopes. Say, *Let's see what other patterns we notice in Venus using one of the oldest tools that was mentioned for helping us see distant objects more clearly by magnifying, or making bigger, their images. Telescopes have been used since around the 1600s—that was over 400 years ago—to observe the night sky. Let's take a look at some of the earliest observations that people recorded of Venus when seen with a telescope.*

Additional Guidance

Telescopes work through the use of refracting lenses, which use the same mechanism of light refraction students investigated in the previous bend of this unit to magnify distant images. Though the mechanism of lens-assisted magnification is beyond the scope of this unit, validate any spontaneous student questions around the history or science behind telescopes, especially those that recognize the role the manipulation of light pathways in magnifying images.

The ideas that lenses can be used to make eyeglasses, telescopes, or microscopes in order to extend what can be seen is a part of a DCI (PS4.C), that is, a target idea for students to have developed by the end of grade 5.

Make observations of the phases of Venus using Galileo's notebook and telescopic photographs. Display **slide N.** Say, *This image is from the science notebook of Galileo—an Italian scientist who lived almost 500 years ago—who was to record observations of Venus from a telescope. The image shown here is of the drawings that Galileo made over the course of several months when Venus was visible in the western sky after sunset.* Orient students to the drawings and when they were drawn. Prompt students to record what they notice and wonder in their notebooks.

7. Share noticings and wondering about Venus and make predictions.

8 MIN

Materials: science notebook, Lesson 7 class consensus models "How does a solar eclipse happen?", "Why don't we see a solar eclipse with every New Moon?", "How often might we see a solar eclipse?"

Compare notice and wonderings of Venus using Galileo's notebooks. Present **slide O.** Give students two minutes to share what they noticed and wondered with a partner.

Compare photographs of Venus. Say, *When telescopes were first invented, there were no cameras to take photographs. But I have some images of Venus in the western sky that an amateur astronomer photographed through a telescope in 2004.* Display **slide P.** Ask a few students to share their responses to the prompts on the slides.

Suggested prompts	Sample student responses
What do you notice?	*The shape of Venus changes over time.* *This is similar to the phases of the Moon.* *The apparent size of Venus changes over time.* *This all matches what Galileo recorded in his science notebook.*
How do these compare to Galileo's observations?	*They are almost the same, like the changing shapes look the same.* *It's hard to tell from the pictures if the size of Venus is changing, so I'm not sure if that's the same.*

Recall our explanatory models for the phases of the Moon and the appearance of Venus in the western sky after sunset. Display **slide Q.** Ask, *Where have we seen something in the night sky changing in a predictable pattern before?* Students should identify Moon phases. Say, *It sounds like we're noticing there are phases of Venus, and these are similar-looking in some ways to the phases of the Moon.* Show them the Phases of the Moon poster you co-constructed in Lesson 6 and ask a student to briefly remind the class of our Moon phases explanation.

Suggested prompts	Sample student responses
How is what we noticed about the phases of Venus similar to the phases of the Moon?	*There is a repeating pattern.* *Some of the shapes are similar.* *Maybe something similar is happening with the Sun's light reflecting off of Venus like it does with the Moon.*
How is what we noticed about the phases of Venus different from the phases of the Moon?	*Venus looks like it changes size, but the Moon does not change size.*

Recall the model of solar and lunar eclipses and connect these ideas to a possible "eclipse" of Venus. Display **slide R.** Have the Lesson 7 class consensus models visible for the class. Ask, *Can someone remind us of what had to happen in order for us to see a solar and lunar eclipse?* Look for a student to say that solar and lunar eclipses occurred only when the orbital path of the Moon around Earth crossed with the orbital path of the Earth around the Sun.

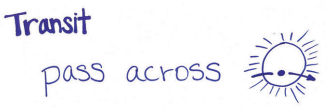
Foreground eclipses. Say, *In addition to being able to explain Moon phases, we also were able to explain two kinds of eclipses involving the Moon: a lunar eclipse and a solar eclipse. Let's consider that kind of phenomena a bit more in the context of Venus.* Then give student groups 2 minutes to discuss if a similar phenomenon (an "eclipse") would occur with Venus. Then take a quick yes/no poll of students around the second question:

- Do you think something similar could happen with Venus?

8. Analyze a video of a transit of Venus.

5 MIN

Materials: science notebook, 8.4 Lesson 13 Transit of Venus (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper to add the co-constructed transit definition to the Word Wall



Motivate the need for additional data. Say, *Let's take a look at some additional data that may help you support or refute your predictions.* Present **slide S.** Summarize the characteristics of the time-lapse video you are about to show:

- The video below was recorded on June 5, 2012, using a digital camera connected to a telescope.
- It is a time lapse where 1 Earth hour = ~1 second in the video.
- The large orange circle is the Sun. The small black dot is Venus.

Show video of transit of Venus. Play 8.4 Lesson 13 Transit of Venus (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Students can record their observations in their notebooks if they wish.

Discuss transit of Venus as a class. Ask students to describe what they saw in the video. Ask students how it differs in appearance from an eclipse. Acknowledge the differences in how much less sunlight Venus blocks than a solar eclipse, and name the phenomenon a transit of Venus. Say, *Another more general word for an eclipse as well as what we just* saw, *which is anytime one object in space passes in front of another one, is the word transit. We can use the word transit to talk about Venus passing between other objects in space like the Sun and our eyes or a camera on a telescope.* Add the definition for *transit* to the Word Wall: *when one object passes in front of another object.* Compare the frequency of this phenomena to a solar eclipse. Present **slide T.** Use the information on the slide to discuss how the frequency of Venus transits compares to the frequency of solar eclipses. Students will say that the transits of Venus appear to happen less frequently than lunar eclipses do.

Additional Guidance

Update the dates of the solar eclipses so they reflect the most recent solar eclipse dates. You can use the website to update the information on **slide T.**

9. Use a model to explain Venus-related patterns.

13 MIN

Materials: *Key: Explaining Venus-Related Patterns*

Connect to prior thinking system thinking. Say, *Earlier we identified the parts of a model that could help explain some of the patterns we noticed with Venus would need to include the Sun, Earth, and observer on Earth, light rays, and Venus. Let's look at two competing models of that system and try to figure out which is best supported by the evidence we have from the patterns of Venus that people have observed over time.*

Distribute a copy of *Competing Models of the Venus, Earth, and Sun System* and *Explaining Venus-Related Patterns* to each student. Display **slide U.** Review the directions on the slide and give students a minute to orient to both handouts. Reminds students to use evidence from their investigations on *Explaining Venus-Related Patterns* to support their answers.

Offer additional supplies if needed. Make note that the directions on *Explaining Venus-Related Patterns* instruct students to use manipulatives first before drawing/writing anything down. Suggest that students can either decide on their own manipulatives to use for this or you can give them some of the manipulatives they used in prior lessons (e.g., foam balls) if they prefer.*

Emphasize that this work is an important formative assessment opportunity, along with the individual exit ticket you will ask them to complete about this model before leaving class. Ask students if they have any questions. Give students the remaining time to work in groups to complete *Competing Models of the Venus, Earth, and Sun System* and *Explaining Venus-Related Patterns.*

Analyze data and predict where other planets might fit into that system model. Remind students that in earlier images of Venus in the sky we saw other planets labeled too. Present **slide V.** Give students 4 minutes to record their responses to these questions on the back of their copy of *Explaining Venus-Related Patterns.*

Collect *Competing Models of the Venus, Earth, and Sun System* and *Explaining Venus-Related Patterns* before starting the next activity.

*** Attending to Equity**
Universal Design for Learning: Allowing student choice in what manipulatives they wish to use for a physical model gives students options in how they want to *represent* the parts and interactions in the system.

Assessment Opportunity

Building towards: 13.B Construct an explanation of the patterns in the apparent size and shape (scale properties) of Venus from Earth as it orbits the Sun.

What to look/listen for: See *Key: Explaining Venus-Related Patterns* for specific guidance on what to look for in each of the small responses for the 4 different phenomena on *Explaining Venus-Related Patterns.* For **slide T** individual responses (next section) that students write on the back of their handouts, look for additional ideas:

- Both Mercury and Venus transits of the Sun have noticeable phases and are never visible at midnight. Both Mars and Jupiter do not match this pattern in any of these categories.
- Mercury's orbit must be similar to Venus, as it orbits the Sun in a path interior to the orbit of Earth.
- Optional: If Mars and Jupiter orbit the Sun, they must follow a path not interior to the orbit of Earth.

What to do: If students struggle to document models similar to those shown in *Key: Explaining Venus-Related Patterns,* ask them to demonstrate the locations of Venus and the Earth related to a light source (e.g., bulb or flashlight) in the room for each of the 4 related phenomena. If students do not identify that Mercury's orbit must be similar to Venus, ask them to demonstrate (with manipulatives) the relative location of Mercury, Earth, and the Sun when Mercury transits the Sun. Ask them what this tells us about how far Mercury must be from the Sun compared to Earth.

10. Record and discuss prediction for other planets. 7 MIN

Materials: chart paper, markers, chart paper to add the co-constructed solar system definition to the Word Wall

Discuss why model B is a better system model. Present **slide W** and use the image on it to discuss why model B helps explain many of the phenomena we observed related to Venus better than model A. Listen for these ideas:

- Even though both model A and model B could produce some patterns for Venus (change in size and phases), model B is the only one that can account for its transit of the Sun.

Present **slide X.** Discuss the related question on it briefly as a class.

Suggested prompt	Sample student responses
Based on what we've figured out about Venus and its orbit, where would you place Mercury, Mars, and Jupiter's orbits if we added them to the system?	*Mercury's orbit must be similar to Venus because we can also see it transit the Sun. This means that Mercury must be between the Earth and Sun.* *Mars and Jupiter, if they orbit the Sun, must follow a path that is outside of the orbit of the Earth because we can't see them transit the Sun.* *I've heard that both Mars and Jupiter both orbit the Sun, too, but farther away from Earth. That would explain why they don't transit the Sun. Would that mean they wouldn't have visible phases too?*

Work with the class to develop a revised system model to include Mercury, Mars, and Jupiter. Add this to a piece of chart paper. While it is not important that the order of the planets be correct, students should offer ideas that Mercury's orbit should be between the Earth and Sun and that both Mars and Jupiter's orbits should be outside of Earth's orbit around the Sun.

Introduce an initial definition for the phrase *solar system*. Say, *As we start adding additional objects and consider other objects that might be in this system with the Sun, it might be useful to have a shorthand way to refer to everything that is interacting in that system. One way some people refer to this is our solar system.* Remind students that we figured out in Lesson 3 that solar meant related to the Sun.

Say, *Because we are now trying to account for patterns in what these objects look like, by figuring out where they are located and how they might be moving in relation to the Sun, they are considered part of the same system or solar system*. Add the phrase *solar system* to the top of the revised system model to include Mercury, Mars, and Jupiter. Add the phrases *Other planets?* and *Other objects?* to the bottom of the model. You may also add an initial definition of *solar system* to your word wall, at this time.

11. Navigate.

6 MIN

Materials: None

Make predictions and identify related technologies. Display **slide Y.** Orient students to the two examples of different telescopes shown on the top of the slide to emphasize how people have built much larger and more powerful telescopes in recent years than existed 400 years ago. Give students 3 minutes to discuss the two questions on the slide. Listen in on student conversations to reference in the next step.

If you heard students mention spacecraft, rockets, probes, rovers, etc. in their discussion, have students share a couple of examples with the whole class. Say, *Since the first telescopes were used to observe planets over 400 years ago, many other technologies have been used to observe these planets in even greater detail, including the ones you mentioned.*

Show **slide Z.** *Say, Some of these technologies have included spacecraft with a variety of scientific instruments that have been launched from Earth and flown near or to Venus, like Mariner 10, which took a photo of Venus that allows us to see its atmosphere in more detail. Venus is very hot, so most spacecraft, including Mariner 10, have flown by or around Venus without going beneath its atmosphere. A mission from the Soviet Union in 1982 did manage to last long enough at the surface of Venus (just a few minutes) to take photographs of the rocky Venus surface and transmit them back to Earth. Several future missions to Venus are planned, including the European Space Agency EnVision orbiter and the NASA DAVINCI+ lander. Most recently, NASA landed the Perseverance rover on Mars in 2020 and have been testing out a small helicopter probe with it (Ingenuity) to collect additional data to send back to Earth.*

Display **slide AA**. Say, *Similarly, many missions have gone to other planets, like Jupiter. Getting closer to this planet has helped us discover that it has many more moons than we can see through telescopes alone. Galileo originally was only able to observe 4 moons of Jupiter through his telescopes. Now we think it may have 79 moons, many much smaller than the 4 moons that originally Galileo saw. These missions either fly by Jupiter and collect data, including photographs, of the planet and its moons on the way out to further reaches of the solar system or orbit Jupiter for a number of years, collecting data and sending it back to Earth. Some missions have actually sent data collection probes into the atmosphere of Jupiter, which have transmitted data back to Earth.*

Show and describe the many missions to other solar system objects over the years. Display **slide BB.** Say, *This infographic shows a subset of NASA missions (supported by a division of NASA called the Jet Propulsion Laboratory) to various planets and other objects in the solar system over the years. There have also been many other NASA missions and missions by other space agencies from around the world that are not represented here. A lot of data from these missions and others is available.*

Make predictions and identify sources of data that would be useful to collect. Display **slide CC.** Ask students to discuss the questions on the slide with a partner and be prepared to share their thinking with the whole class next period, so we can decide as a class what we want to start looking for if we had additional data from these other data sources we've identified.

Alternate Activity

Extension Opportunity: If time permits in class or as home learning, provide *Gravity Assist Podcast Transcripts* as an optional home learning to help students connect to current scientists from a plethora of backgrounds who are helping gather data about objects in the solar system (and beyond). There are short time clips mentioned and transcribed on *Gravity Assist Podcast Transcripts* but if time permits students may listen to the whole podcasts. Also, remind students to turn on the closed captioning on as they listen.

Additional podcasts can be found on the NASA website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

End of day 2

12. Identify other types of data to collect. 3 MIN

Materials: None

Identify other types of data we would want to collect with equipment sent to other objects in the solar system. Display **slide DD.** Ask, *What sort of data would you want to be able to collect if you could send data collection equipment to other objects in our solar system?* Accept all responses.

13. Analyze and interpret data from infographics. 20 MIN

Materials: science notebook, *Looking for Patterns in the Solar System Infographics*, *Analyzing and Interpreting Data from Infographics Close Reading Protocol*

Explain the sources of the data for the infographics. Explain that you have a series of info cards that include photographs and data collected from the type of instruments we have been discussing, from measurements taken from dozens of different kinds of data collection missions sent to different planets, moons, and other objects in our solar system.*

Setup the science notebook. Display **slide EE.** Give students a minute to set up their notebooks, as displayed on the slide.

Work in small groups with infographics. Distribute *Looking for Patterns in the Solar System Infographics* to each group. Organize students in groups of three to four. Use **slide FF** to help explain the infographics. Say, *An infographic combines the words "information" and "graphic." They are visual representations of information and data that are designed to tell you a lot about a topic very quickly. We can use some of the same close reading strategies that we use when we read text to interpret an infographic.*

Additional Guidance

All of the *Looking for Patterns in the Solar System Infographics* are included in a single handout. They can also be accessed digitally if students want to zoom in on particular sections. If you would like to separate the infographics so groups can spread them out on a table and manipulate, you or students can trim the top and bottom borders of each infographic. Align the bottom of the first page of each infographic to the top of the next page and use tape to attach them.

It is OK for groups to only analyze data from the first four infographics and not all of them. You may employ student choice and let groups choose their perceived level of challenger or assign readings.

Display **slide GG**, which has the close reading protocol. This protocol is designed specifically to focus students on obtaining information from infographics. Go over this briefly and then distribute out *Analyzing and Interpreting Data from Infographics Close Reading Protocol* to set students on the task of interpreting their infographics. Please distribute *Infographic Text* which contains the infographic text (on white background) of the color infographics to make printing and annotation easier. The infographics images will be best viewed digitally or color printed (in the student edition or you can print the handout and cut and tape them together to make a class set, if you have access to a color printer).

*** Supporting Students in Three-Dimensional Learning**

Three-dimensional learning is enhanced by connections to engineering, technology, and applications of science. Scientists use engineering advances to support the design of investigations to gather data about far away worlds. These infographics are an opportunity to highlight how advances in space engineering have led to important discoveries about objects in our solar system.

*** Attending to Equity**

Supporting Emergent Multilingual Students: Any education in science and engineering needs to develop students' ability to read and produce domain-specific text. As such, every science or engineering lesson is in part a language lesson, particularly reading and producing the genres of texts that are intrinsic to science and engineering (NRC Framework, 2012, p. 76). Emergent multilingual students will require additional support for this

Infographic Titles	Reading Level
1. *Inner Planets*	9
2. *Our Moon*	7
3. *Mars*	9
4. *Outer Planets*	8
5. *Jupiter's* Moons	6
6. *Saturn's Moons*	7
7. *Dwarf Planets*	8

practice. In particular, it is helpful to be explicit about the structures and syntax that are unique to scientific texts.

Additional Guidance

Note that while the scientific information in each of these infographics is equally rigorous, they are written at four different reading levels to support differentiation. You may choose to group students strategically so that students who need more support with obtaining information from scientific texts are distributed among mixed-expertise groups or are assigned infographics at a sixth or seventh-grade reading level within their group, while students who are looking for a challenge are in groups assigned infographics at a ninth-grade reading level. If your entire class would benefit from the sixth and seventh-grade level infographics, you can use only the *Moons of Jupiter* and *Saturn, Our Moon, and Mercury and Venus.* Additionally, these infographics are meant to be built around student questions from class and the Driving Question Board. If students do not ask about one of the objects in *Looking for Patterns in the Solar System Infographics,* especially infographics 5–7, you do not need to share that infographic and the remaining infographics and the content will still be coherent and aligned to the NGSS.



As students work, move about the classroom and listen in to students' conversations and observe the tables in their notebooks. Use probing questions to help students clarify their ideas.* Listen for groups to ask questions about how all of these objects are organized in the solar system.

Assessment Opportunity

Building towards: 13.C Analyze and interpret data to identify patterns in and between different scale properties for planets and some of their moons in our solar system (including relative size, orbital distance from the Sun, surface features, if any, and atmosphere).

What to look/listen for: As students analyze planetary and other solar system object data

- Look for diversity of ideas that will help generate ideas about the scale properties of the solar system and motivate needing the mechanisms behind why the solar system is organized the way it is. Such as
  - comparing the size of objects in the solar system relative to where they are located;
  - comparing composition of different planets relative to other planets;

- beginning to compare how long it takes the planet to rotate on its axis and how long it takes to go around the main object it orbits; and
- beginning to notice a relationship between location within the solar system and object size, object speed, and object orbital period.

If students struggle to describe accurate patterns that emerge from the data, including the correlation between average orbital distance, orbital period, and average orbital speed, then have them choose two objects from different infographics and ask specifically, is there something similar about these two objects? Is there something different about these objects?

Additional Guidance

During and after student analysis of the data in the infographics, ask students questions that encourage them to be metacognitive about the information they are obtaining. Example questions follow:

- How did talking with your group help you make sense of the information in the infographic?
- How is getting information from an infographic different from getting information from a reading?
- What additional things did you need to do when you were processing the infographic that you might not do when you are just reading?*

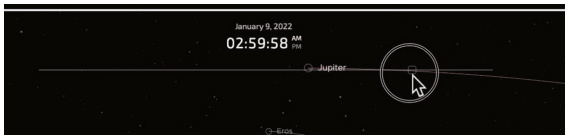
14. Identify more patterns between solar systems objects. 10 MIN

Materials: science notebook, 8.4 Lesson 13 NASA Eyes on the Solar System Tour (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Use a computer model to identify more or elaborate on patterns we noticed in the solar system. Say, *Some of your group discussions started to ask about how all of these objects are organized in the solar system. I have a video we can watch that will give us a tour of the solar system.* Display **slide HH.** Play 8.4 Lesson 13 NASA Eyes on the Solar System Tour or project NASA's Eyes website (See the **Online Resources Guide** for links to these items. **www.coreknowledge.org/cksci-online-resources**) and use it in a similar way to give students a way to notice patterns in the solar system. As you explore the solar system simulation, ask students to note composition and information about satellites and celestial environments. Students can also note that the direction of orbit of each of the solar system objects is in the same direction as the orbit of the Earth around the Sun. If they don't, ask them to look for similarities and differences in how the solar system objects are moving.

Additional Guidance

The 8.4 Lesson 13 NASA Eyes on the Solar System Tour video is about 15 minutes in length and shows live data about objects in the solar system. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) You do not need to show the entire screencast but can focus on the objects your students have the most wonderings about after the infographics. Watch the screencast yourself before the lesson to help learn the features embedded in the program, such as clicking 6 times on the time and date to get the scroll bar to speed up or slow down time (the instructions happen at about 4 minutes into the screencast). You can then drag the box on the scroll bar to speed up time.



NASA



NASA

Ask students to share some of the patterns they noticed and questions they were wondering.

Suggested prompts	Sample student responses
What patterns did you notice?	*All solar system objects orbit the Sun in the same direction (counterclockwise if looking above Earth's Northern Hemisphere).* *There are nested patterns of orbits, but smaller objects always orbit larger objects.* *Most objects are orbiting the solar system in a similar plane.* *Most spins/rotations are in the same direction.* *The solar system objects look like they are moving in front of the stars or what looks like stars, and the stars don't look like they are moving.* *Larger objects are orbited by smaller objects (Sun-planets/asteroids; planets-moons/rings).*
What questions are you wondering?	*Why do all of these objects (planets and natural satellites) have a steady orbital path?* *What explains the pattern in speeds, where the closest objects to the Sun are also the fastest?* *What exactly is the role of gravity in explaining these paths?* *Why are the paths of orbit in the same direction? Why are most of the spins/rotations in the same direction?* *Why are all of the rocky planets clustered together near the Sun, with the gaseous and icy planets farther from the Sun?* *Why do some planets have moons/rings orbiting them and others don't?* *Why are all the solar system objects orbiting in nearly the same plane?*

Additional Guidance

If students do not mention the pattern that solar system objects appear to be moving in front of the stars, or what looks like stars, and the stars don't look like they are moving, point out to students that the stars seem to be a backdrop for the solar system. You can also reference *Venus in Cultures from Around the World* and how other cultures noticed that planets moved differently from stars in the night sky.

Alternate Activity

Extension Opportunity: If students want or need additional support in considering the scale of objects within the solar system or additional patterns, this is a good opportunity to introduce students to a simulation of scale websites. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

If your students are interested or need additional experience to connect to the scale of the solar system, you could spend an extra day building a scale model of the solar system with the class, either physically or virtually. If your school has a football field, you can use a ping-pong ball for the Sun (and place it on the zero-yard line), peppercorns for the four gas giants (Jupiter, Saturn, Uranus, and Neptune), and grains of kosher salt to represent the terrestrial planets (Mercury, Venus, Earth, and Mars). The planets should be held by students as follows:

- Mercury at the 1-yard line
- Venus at the 2-yard line
- Earth at the 3-yard line
- Mars at the 5-yard line
- Jupiter at the 17-yard line
- Saturn at the 32-yard line
- Uranus at the 64-yard line

In addition, if students want to explore deeper and more complex patterns in the solar system using the simulation you used as a class, you could send them home with the link to the NASA website. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Furthermore, if students are struggling to grasp the size and scale of the solar system consider showing a video on size and scale. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Additional Guidance

Students may have questions about Vesta and Pluto. If they do, you may mention to students that Vesta is a part of the asteroid belt that orbits the Sun between Mars and Jupiter and that Pluto is one of several "Kuiper belt" objects that orbit the Sun beyond Neptune. Pluto was once considered a planet but no longer is because it orbits the Sun in the neighborhood of many other objects, whereas true planets orbit the Sun in an orbit without many other objects other than their moons or satellites.

15. Update Progress Trackers and navigation.

12 MIN

Materials: science notebook

Update Progress Trackers to reflect new understandings. Present **slide II** and ask, *Looking back, what did we accomplish and figure out the past few days? Let's take a few minutes to process this on your own in your Progress Trackers.* An example of possible responses you may see in individual Progress Trackers is shown here.

Question	What we figured out in words and/or pictures about patterns in the sky	How does this connect to or influence me or my community or other communities?
What new patterns do we see when we look more closely at other objects in the sky?	• Even though Venus and other object in the sky look like stars, they move differently and are other things, like planets or moons. • Inner objects are rocky and small, farther out objects are large ard gaseous, farthest objects are icy. • Moons are going around planets, and planets are goirg around the Sun. • Planets spin/rotate at different speeds.* • The planets closer to the Sun are generally smaller and orbit faster than the farther away planets.	Answers will vary, but some sample ideas could include the following: • Many cultures are connected to Versus but in their own way. • Some things I thought were stars but move differently are actually planets.

Navigate to the next lesson. Display **slide JJ**. *Say, now that we have done some individual processing of what we figured out and connections, what wonderings do you have about the solar system after analyzing the data in the infographics and taking a tour of the solar system?* Have students turn and talk about the prompt with a partner before asking for a few volunteers to share. Listen for students to want to know more about how the objects stay on the same path as they orbit the Sun or around a planet or why some objects orbit planets (moons) and other objects orbit the Sun.

*** Attending to Equity**

Universal Design for Learning: As students share, clarify what they mean when they use the words spin or rotate to make sure that the class is on the same page about the difference between spinning/rotating and orbit of the object. Even though the DCI element of orbit is built by the end of 5th grade and adding Earth spinning on an axis is built earlier in this unit, this is the first time students are looking across many objects in the solar system for these patterns. To support students in expression, you can ask for students to share examples, pictures, or use their hands or other manipulatives to show what they mean.

ADDITIONAL LESSON 13 TEACHER GUIDANCE

Supporting Students in Making Connections in ELA

CCSS.ELA-LITERACY.RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts.

In this lesson, students read about the cultural significance of Venus and the observations made of Venus by various ancient peoples. Students cite specific examples from the text when comparing the connections ancient people made to Venus. Students also use evidence from this text when discussing the patterns of Venus's appearance in the sky and how those patterns could inform their model of the solar system.

CCSS.ELA-LITERACY.RST.6–8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).

In this lesson, students read and make sense of infographics to integrate quantitative and qualitative information by analyzing and interpreting data from infographics.

Space On-Screen

1 Director Spotlight
2 Facts in the Fiction
3 Science from Fantasy
4 Is There Anybody Out There?

Literacy Objectives

- ✓ Distinguish cause(s) and effect(s) related to celestial structures and gravity.
- ✓ Argue a position on the interactions between entertainment and science.
- ✓ Support a position on the interactions between entertainment and science with evidence.

Prerequisite Investigations

Assign the Science Literacy reading and writing exercise *after* class completion of this lesson group:

- Lesson 12: Why does the Moon always change color during a lunar eclipse?
- Lesson 13: What new patterns do we see when we look more closely at other objects in the sky?

Instructional Resources

Student Reader



Collection 4

Science Literacy Student Reader, Collection 4
"Space On-Screen"

Exercise Page



EP 4

Science Literacy Exercise Page
EP 4

Literacy Exercises

- Read varied text selections related to the topics explored in Lessons 12–13.
- Evaluate the reading selections according to provided prompts and criteria.
- Compare and contrast information gained from reading text with information gained from class investigation.
- Prepare a well-reasoned paragraph in response to the reading.

Standards and Dimensions

NGSS

Disciplinary Core Ideas ESS1.A: The Universe and Its Stars Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. (MS-ESS1-2)

PS2.B: Types of Interactions Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. (MS-PS2-4)

Science and Engineering Practice: Obtaining, Evaluating, and Communicating Information

Crosscutting Concepts: Patterns; Cause and Effect; Connections to the Nature of Science

CCSS

English Language Arts

RST.6-8.4: Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.

RST.6-8.6: Analyze the author's purpose in providing an explanation, describing a procedure, or discussing an experiment in a text.

WHST.6-8.6: Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

Core Vocabulary

Core Vocabulary: Core Vocabulary terms are those that students should learn to use accurately in discussion and in written responses. During facilitation of learning, expose students repeatedly to these terms. However, these terms are not intended for isolated drill or memorization.

gravitational force

Language of Instruction: The Language of Instruction consists of additional terms, not considered a part of Core Vocabulary, that you should use when talking about any concepts in this exercise. Students will benefit from your modeling the use of these words without the expectation that students will use or explain the words themselves.

black hole **electromagnetic radiation**

A Glossary at the end of the Science Literacy Student Reader lists definitions for Core Vocabulary and selected Language of Instruction.

1. Plan ahead.

Determine your pacing to introduce the reading selections, check in with students on their progress, and discuss the reading content and writing exercise. If you are performing Science Literacy as a structured, weekly routine, you might implement a schedule like this:

- Monday: Designate a ten-minute period at the beginning of the week to introduce students to the assignment.
- Wednesday: Plan to touch base briefly with students in the middle of the week to answer questions about the reading, to clarify expectations about the writing exercise, and to help students stay on track.
- Friday: Set aside time at the end of the week to facilitate a discussion about the reading and the writing exercise.

You'll proceed with the in-class lesson investigations during this week.

2. Preview the assignment and set expectations. (Monday)

- Let students know they will read independently and then complete a short writing assignment. The reading selection relates to topics they are presently exploring in their Earth in Space unit science investigations.
- The reading and writing will be completed outside of class (unless you have available class time to allocate).
- Preview the reading. Share a short summary of what students can expect.
    - *First, you will read a fictious interview with the director of a new streaming series called "Infinite Universe." She'll describe the experiences that inspired her to become a director.*
    - *Next, you'll read an analysis of the good and bad science in the 2015 film The Martian.*

- *Then, you'll encounter a simulated news article about how a popular 2014 movie inspired astronomers to come up with new insights about black holes.*
- *Finally, you'll read an article that presents a difficult question about intelligent extraterrestrials and describes four possible answers.*

- Distribute Exercise Page 4. Preview the writing exercise. Share a summary of what students will be expected to deliver. Emphasize that Science Literacy exercises are brief. The focus is on thoughtful quality of a small product, not on the assignment being big and complex.
  - *For this assignment you will be expected to generate a well-reasoned paragraph to support a claim about science fiction entertainment and science.*

Exercise Page



EP 4

- Remind students of helpful strategies they can employ during independent reading. Offer the following advice:
  - *The reading should take approximately 30 minutes to complete.* (Encourage students to break reading into smaller sections over multiple short sittings if their attention wanders.)
  - *A good reading strategy is to scan through the collection first to see the titles, section headers, graphics, and images to see what the selections are going to be about before fully reading.*
  - *Next, "cold read" the selections without yet thinking about the writing assignment that will follow.*
  - *Then, carefully read the Exercise Page to understand the expectations for the writing part of the assignment.*
  - *Revisit the reading selections to complete the writing exercise.*
  - *Jot down any questions for the midweek progress check in class.* (Be sure students know, though, that they are not limited to that time to ask you for clarification or answers to questions.)

3. Touch base to provide clarification and address questions. (Wednesday)

Touch base midweek with students to make sure they are on track while working independently. You may choose to administer a midweek minute-quiz to give students a concrete reason not to postpone completing the reading until the last minute. Ask questions such as these, and have students jot answers on a half sheet of paper:

Suggested prompts	Sample student responses
What were two strengths of the work of Carl Sagan?	*He was a good scientist and a good communicator/novelist.*
What is "gravity assist," and what role did it play in the movie called The Martian*?*	*Gravity assist uses the gravitational pull of a planet or moon to change the direction a spacecraft is traveling. In* The Martian*, the rescue mission uses gravity assist to move a spacecraft from Earth to Mars.*
How did art inspire science during the making of the film Interstellar*?*	*The computer graphics designed to show a black hole led scientists to make new discoveries about black holes.*
What is the Drake equation?	*It is a math calculation that tries to predict how likely it is that there is intelligent life in the universe.*

Ask a few brief discussion questions related to the reading that will help students tie the text content to students' classroom investigations.

Suggested prompts	Sample student responses
What sky patterns would a person living on Mars observe that are similar to those people on Earth observe?	*the rising and setting of the sun, star trails, the motions of Earth and other planets in the night sky, Earth phases*
Based on the clues from the selection, how did gravity affect living on Mars?	*Gravity held the human on the ground so he could walk and work on the surface.* *Dust blown by the wind settled on the ground or other surfaces when the wind died down.*
How did watching the Lesson 16 video from the California Academy of Sciences, called "Tour of the Universe," support your understanding of the Drake equation?	*Seeing how old and huge the universe is makes me think that it is very likely there is, or was, intelligent life beyond Earth.* *Seeing how long light takes to move to Earth from distant parts of the universe makes me think that intelligent life may have existed in the past but by the time we get the signals, they will be long extinct.*

- Refer students to the Exercise Page 4. Provide more specific guidance about expectations for students' deliverables due at the end of the week.
  - *The writing expectation for this assignment is to develop a well-constructed paragraph to support a claim about the connection between entertainment and science.*
  - *That means using evidence from the readings to support your reasoning about why the claim is true.*
  - *You can also use evidence from your own experiences with science fiction media to support your claim.*
  - *The important criteria for your work are that you support the claim you have chosen with a paragraph that is well organized and makes references to the selections in Collection 4.*
- Answer any questions students may have relative to the reading content or the exercise expectations.

Exercise Page



EP 4

4. Facilitate discussion.

(FRIDAY)

Facilitate class discussion about the reading collection and writing exercise. This collection focuses on the role of entertainment media in communicating about space science and building the case for public support of science to answer the question, "Is there anyone out there?"

Student Reader



Collection 3

Pages 38–45 Suggested prompts	Sample student responses
What is the general purpose of the first selection, "Director Spotlight"?	*It explains how a person's early experiences with a science television show can influence their choice to direct a show about the universe.*
What are some advantages for scientists of being good communicators?	*A good communicator can make students and other nonscientists get interested in learning about science and get other scientists interested in hearing about the questions they ask.*
What is Angela Houseman's new series about? Did she communicate it well?	*It's about the universe, but most of the images are from places on Earth, so maybe it is more about Earth in the universe.* *Her description is a little hard to follow, especially if you never saw the series* Cosmos.
What is the general purpose of the second selection, "Facts in the Fiction"?	*It explains what science the movie* The Martian *got right and got wrong.*
Suppose you wanted to find out more about the scientific accuracy of other scenes of this movie. How would you find reliable, unbiased sources and avoid misinformation?	*I could ask a reference librarian to point me to reliable sources.* *I could search online for websites about this movie authored by space scientists and engineers.* *I could avoid social media where people say anything they wish and you cannot tell what is correct.*
If the main character in the movie is looking at the Martian sky, what celestial structures would he see, and how would they appear?	*Mars's moons would look fairly large and would have phases.* *Due to Mars's place in our solar system, Jupiter and Saturn would look quite large, Earth very small, and Venus and Mercury might not be visible at all.* *The sun would look smaller and dimmer than it does from Earth.*

SUPPORT—If you are using the recommended word envelope convention, check the envelope to see if it contains any words, phrases, or sentences that students need help understanding. Read key sentences aloud, and provide concise explanation.

Online Resources



SUPPORT—To provide context for understanding the goals of the fictitious director in the first selection, show students one or more videos from Carl Sagan's series called *Cosmos*. Ask students to describe the style of the show, including the language used.

CHALLENGE—Interested students may enjoy the challenge of examining the entire Drake equation and explaining it to the class.

Pages 38–45 Suggested prompts	Sample student responses
What is the general purpose of the third article, "Science from Fantasy"?	*It explains how the makers of the movie* Interstellar *worked with scientists and how both benefited.*
Why could this selection also have been titled "Science from Art"?	*because computer graphic artists worked with scientists to create computer simulations that helped explain how matter and light behave near black holes*
What questions about black holes are on our Driving Question Board? What further questions do you have after reading this article?	*Is there a black hole in our solar system?* *What does a black hole look like through a telescope?* *How do "supermassive" black holes differ from other black holes?* *Why do most galaxies have a black hole at their centers?* *How can gravity capture light?*
What is the general purpose of the fourth article, "Is There Anybody Out There?"	*It explores answers to the question of why we have no evidence of alien intelligences—yet.*
How does the fourth selection help you answer the question from this unit's preface, "Is it plausible we will find intelligent life among the stars?"	*The fourth article uses the Drake equation to explain why it is plausible that there is intelligent life out there.*
Why do you think the SETI project has been so long-lasting, even after the US government canceled its funding in 1992?	*because the Drake equation gives scientists reason to think that it is plausible that intelligent life is out there, even if it takes huge effort to find the signals* *maybe because nongovernment funders think the project is worth supporting*

5. Check for understanding.

Evaluate and Provide Feedback

For Exercise 4, students should, from a topic sentence that they select, write a well-constructed claim-evidence-reasoning paragraph about how science and science fiction entertainers, the public, and scientists can support one another.

If students choose the first topic sentence, they might cite the popularity of science fiction movies such as *The Martian* and *Interstellar* as compelling ways to expose young people to scientific ideas and inspire them to learn more. Examples from students' personal lives might include video games, podcasts, and television shows.

To support the second claim, students may say that movies such as *The Martian* and *Interstellar* and other entertainment that are scientifically accurate or ask scientific questions help make a piece of fiction more plausible and scarier. For example, in *The Martian*, the director might have gotten the danger of winds wrong, but getting all the rest correct made the story stronger.

Supporting the third claim might include students' personal experiences listening to scientists and losing interest due to their presentation styles. Students may cite Carl Sagan's fiction writing and successful television show to reason that he was equal parts entertainer/communicator and scientist.

To support the fourth claim, students should explain that science literacy gives people another way to think about science fiction entertainment, such as the movie *Contact*. Knowing the different possible answers to the Fermi paradox makes the movie's story more engaging and understandable.

Structurally, a student's argument should be composed in a complete, well-organized paragraph. Use the rubric provided on the Exercise Page to supply feedback to each student.

LESSON 14

Why do some solar system objects orbit planets and others orbit the Sun?

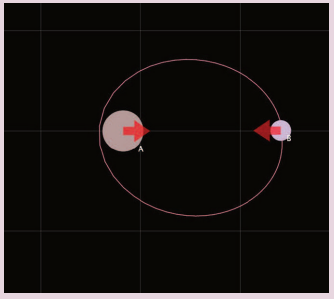
Previous Lesson

We revisited DQB questions we have not yet addressed and decided to focus on other objects in our solar system. We gathered information from a reading to identify connections and observations others have made about one planet in the solar system (Venus). We noticed additional patterns in other observations of Venus and recorded new questions about these. We used a model showing the relative position of motion of Venus and Earth in the system to explain these patterns. We analyze the scale properties of other planets to look for other patterns.

This Lesson

Investigation

2 DAYS



We share initial ideas about patterns of motion in the solar system, which leads us to conduct a cause-and-effect thought experiment around those patterns. We use a simulation to investigate how changing distance and size affects an object's orbit around another object in the solar system. We build understanding as a class about the relationship between size, distance, and the strength of the force of gravity.

Next Lesson

We will analyze images of craters and watch a video that models the formation of the solar system. We will develop an individual and a class consensus storyboard to support the claim that the solar system was formed from a disk of gas and dust, drawn together by gravity.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1- 3, MS-PS2-4, MS-PS4-2

What Students Will Do

14.A Develop and revise an initial model of the Earth-Moon system to show the location, strength, and interaction of gravitational forces in the system.

14.B Use a simulation of a two-object system to produce data that can be analyzed to identify patterns to determine how changes in the mass or distance between the objects in the system affects the strength of gravitational forces between those objects in space.

What Students Will Figure Out

- Gravity is an attractive force between all matter.
- More massive objects have stronger attractive gravitational forces between them than objects that are less massive.
- Closer objects have stronger attractive gravitational forces between them than objects farther away.
- More circular orbits occur when there is the right combination between the force of gravity and the speed of the orbiting object.

Lesson 14 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	6 min	**NAVIGATION** Revisit wonderings from Lesson 13.	A-B	
2	10 min	**DISCUSS INITIAL IDEAS ABOUT PATTERNS OF MOTION** Share initial ideas for connections between the patterns we see and why objects are moving that way.	C-D	*Looking for Patterns in the Solar System Infographics*, "Phases of the Moon" poster from Lesson 6
3	10 min	**CONDUCT SOME THOUGHT EXPERIMENTS** Review examples of cause-effect relationships. Discuss predictive cause-and-effect relationships for the Earth-Moon system.	E-G	
4	6 min	**CONNECT TO PRIOR EXPERIENCES** Discuss prior experiences with gravity in the context of weather and prior experiences with fields in the context of magnets.	H	
5	7 min	**DEVELOP AN INITIAL MODEL TO EXPLAIN THE EFFECT OF CHANGING THE SIZE OR LOCATION OF AN ORBITING OBJECT** Individually develop an initial model to explain gravitational forces on a two-object system.	I-J	*What causes one solar system object to move around another one?*
6	6 min	**IDENTIFY VARIABLES TO CHANGE AND MEASURE IN A SIMULATION OF GRAVITY INTERACTIONS BETWEEN TWO OBJECTS** Identify variables that would affect the orbit of objects in the solar system.	K-L	*What causes one solar system object to move around another one?*

End of day 1

Part	Duration	Summary	Slide	Materials
7	7 min	**PREVIEW THE INTERACTIVES AND MAKE PREDICTIONS** Introduce variables available for manipulation and observation in the two-object system computer interactives so students can formulate predictions.	M-S	*Simulating a Two-Object System*, *What causes one solar system object to move around another one?*, computer, projector, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
8	16 min	**INVESTIGATE THE INTERACTIONS BETWEEN TWO OBJECTS** Use a computer interactive to collect data in small groups in order to answer investigation questions.	T	*Simulating a Two-Object System*, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
9	15 min	**BUILD UNDERSTANDING ABOUT THE INTERACTIONS OF GRAVITY FORCES BETWEEN TWO OBJECTS** Facilitate a Building Understandings Discussion to process the key take-aways from the simulation.	U	*Simulating a Two-Object System*, chart paper, markers, (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
10	6 min	**NAVIGATION** Determine our next steps.	V	DQB

End of day 2

Lesson 14 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Looking for Patterns in the Solar System Infographics* • *What causes one solar system object to move around another one?* • *Simulating a Two-Object System*	• Exploring Orbits simulations (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)	• "Phases of the Moon" poster from Lesson 6 • computer • projector • (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers • DQB

Materials preparation (15 minutes)

Online Resources 

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test Exploring Orbits simulations and create a plan for student groups to access them at (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Students can complete the simulations individually or in small groups. Each group will require a computer with a web browser.

Use Exploring Orbits Introduction video at 8.4 Lesson 14 Exploring Orbits Introduction to orient yourself to the simulations, including manipulating the mass and the speed of the objects and the distance between the objects. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) This video introduces students to the simulation, though you may choose to do this by introducing it yourself.

Prepare the "Factors that Affect Orbit" chart.

Be sure you have materials ready to add the following word to the Word Wall: ***gravitational forces***. Do not post this on the Word Wall until after your class has developed a shared understanding of its meaning.

Lesson 14 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students use a computer interactive simulating a two-object system to investigate the factors that keep the solar system organized and objects in orbit around each other. Students determine several qualitative causal relationships that affect the strength of the gravity force pairs on two solar system objects of their choice. They notice that the mass of an object and the distance between that object and another object affect these force pairs. Students determine changes in these affect the strength of this force and the speed of the orbiting objects and that in turn affects whether the object will stay in orbit around a 2nd object, will collide with it, or will move away from it.

Where We Are NOT Going

Students also do not develop quantitative relationships among mass, distance, speed, and gravity force in the form of Newton's law of universal gravitation. While students who have recently completed *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)* may make connections between forces due to gravity and forces due to magnetism or electricity, developing an explanation of how the distance forces are related to gravitational fields or how the field stores potential energy in the system, and/or how forces transfer energy into or out of that field is not the goal of this lesson. Students do not need to be able to explain gravity forces' role in the formation of the solar system or at larger scales than the solar system at this time. This will be done in the next lesson.

LEARNING PLAN FOR LESSON 14

1. Navigation

6 MIN

Materials: science notebook

Additional Guidance

It may be helpful to have the *Looking for Patterns in the Solar System Infographics* from Lesson 13 available if students want to look back at any of the patterns visually or add additional data or patterns to their notebook. If students followed the alternate guidance from Lesson 13 to explore for more patterns at home using online simulations, make sure to probe for those patterns in this discussion and give time for them to add those patterns to their notebook.

Recall patterns identified in observations of the solar system last class. Display **slide A.** Have students take out their science notebooks and share one pattern they figured out about the solar system that could help explain something they see in the sky either with their unaided eyes or with a tool. Then say, *We had all these questions about why and how objects are moving in the solar system. What were some of the questions we had about patterns or specific objects?*

Listen for students to say the following:

- Why are these objects moving in circles and not flying away or crashing?
- Why does everything out there go around something?
- Why are certain things going around something and not others?
- Why do Moons go around planets and not the Sun?
- What keeps the objects from flying away, like the Moon from Earth?
- Why do some plans have many moons, some have one, and some have zero?

Turn and talk about the patterns in student questions. Say, *Turn to your partner and discuss if you see a theme emerging from the class questions.* Walk around the room and listen for themes about how objects are moving in the solar system and how those movements seem to have consistent patterns.

Say, *We seem to have a similar trend in our questions. They seem related to the paths of motion we saw in all the objects in the solar system.*

Listen for students to make explicit connections to specific objects they had questions about in the solar system. If your students mentioned other moons or planets in their questions, you can replace those objects in your question to them and use their language.

Say, *Let's take a few minutes to make public our current thinking about how and why things move the way they do in the solar system. Before we do that, let's consider how the patterns of motion we saw for all these objects in space connect to our lives here on Earth.* Show **slide B.** Discuss the related questions on the slide as a class.

Suggested prompts	Sample student responses
How does the path that Earth moves through space affect the patterns we experience on Earth?	*It affects how long the seasons are and when they are.* *It affects how long days are.* *It affects how long a year is.*
What other objects in our solar system and the paths they follow through space affect the patterns we experience on Earth?	*the Moon* *Venus and the other planets*
How would what we experience be different if Earth and these other objects didn't follow the patterns of motion through space that they do now?	*Accept all answers.*

2. Discuss initial ideas about patterns of motion.

10 MIN

Materials: science notebook, *Looking for Patterns in the Solar System Infographics*, "Phases of the Moon" poster from Lesson 6

Stop and jot about how and why two objects move the way they do in the solar system. Display **slide C.** Have each student pick any pair of objects in our solar system they noticed that tend to move around each other and write that pair of objects down in their notebook. Say, *A lot of us were wondering why the objects in our solar system have the patterns of motion they do, and we just started considering what would be different if they didn't follow the patterns of motion that they do. Take a moment to write an initial explanation in your notebook for how and why your objects move the way they do around each other.* As students are writing their predictions, walk around the room looking for ideas to bring into the whole class discussion. Give four minutes for this.

Discuss parts of the system in these explanations.

*** Attending to Equity**

Universal Design for Learning: The goal in this moment is twofold: (1) to support *engagement* by optimizing relevance for students by allowing them to choose the objects they will later model, and (2) to have students begin to think about how those objects interact as part of a system and what we could do to figure out those interactions in the next part of the lesson. Accept all examples from students, including ones that only meet #1.

Suggested prompts	Sample student responses
Before we try and figure out what is happening, let's share our ideas about what we think is happening between each of these pairs of objects in these systems. Can you share what were the two objects in the system you were trying to explain?	*Moon and Earth* *Earth and Sun* *Jupiter and one of its moons*
How did the two objects move around each other?	*The Moon orbits Earth.* *Earth orbits the Sun.* *Jupiter's moons orbit Jupiter.*
We've each broken down the larger solar system in smaller parts and identified similar motion occurring between these pairs of objects. What does that tell us about the causes for the motion we are seeing in these different parts of the system? Would the causes be similar or different?	*The causes must be similar, since the motions are similar.*

Connect to system thinking. Say, *When scientists recognize similar patterns of motion for different objects across a system, they often try to consider what the underlying cause is for this similarity. To do that, they might start with one part of the system they have the most familiarity with and figure out what is happening between the objects in those smaller parts or subsystems of the larger system before seeing if that same model can explain other objects in the system.* Ask students for examples of where they have done that type of system thinking before in other non-space systems. Students are likely to suggest the following examples:

- In *Healing Unit* and *Unit 7.3: How do things inside our bodies work together to make us feel the way we do? (Inside Our Bodies Unit)*: how there are different systems and subsystems working in the body that can affect what happens in other systems/systems to heal or provide matter and energy.
- In *Magnets Unit* by dissecting a speaker to identify the important parts of the system, which allowed us to see how magnets and electricity in the coil of a wire could work together to cause the speaker to vibrate.
- In *Cup Design Unit*: how the lid affects cooling/heating in the cup unit, how reflective material affects it, and how wall thickness affects it.
- In *Everest Unit*, determining where the breaks in bedrock could be found across a continent and thinking about how that entire system (a relatively continuous piece of bedrock or plate) might move, before considering whether there are other parts of Earth that are moving in similar ways.

Identify the parts and properties of a two-object system. Propose starting with developing a model of a two-object system that we have more familiarity with, and revising our model for it, before we consider how that revised model might apply to other pairs of objects in our solar system.

Reference the "Phases of the Moon" poster developed for the Earth-Moon system from Lesson 6. Point out that this system is one that we developed a pretty detailed model for and have a lot familiarity with now, so it might be a good

candidate to start with to try to develop an answer to the question we are now considering. Add this question to the board:

What **causes** one object (e.g., the Moon) to move around another object (e.g., Earth) in the pattern of motion that it does (effect)?

Propose that we do some system thinking to recap what we know about the motion, parts, and interactions in this system to see if we can make progress on the cause part of this question. Display **slide D.**

Suggested prompts	Sample student responses	Follow-up questions
What do we already know about the motion of the Moon relative to Earth?	*The Moon goes around Earth in an orbit.*	*And what do we know about how long it takes for the Moon to complete one orbit around Earth?*
What is similar and what is different about both of these objects in the Earth-Moon system?	*The Moon and Earth are both made of rock.* *The Moon and Earth are relatively close together, in terms of how far some things are in the solar system.* *Both the Moon and Earth are spinning.* *The Moon is smaller than Earth.*	*What does that tell us about which of these two objects would be more massive?*

3. Conduct some thought experiments.

10 MIN

Materials: None

Introduce thought experiments as another way to engage in system thinking. Say, *Another way to make progress on our cause and effect thinking, in any system, is to carry out thought experiments on the parts and properties in the system. We can do this by identifying a single variable that describes part of the system and asking ourselves, what would happen if the value of the variable changed in our system? Or, in other words, if we change variable X, what would happen to affect Y?*

Connect to cause-and-effect thinking from a prior unit on distance forces. Remind students that they used cause-and-effect thinking to refine the question they asked in their prior unit: *Magnets Unit*. If needed, present **slide E** to refer to the sentence stem on this slide as one that students had seen before in that unit.

Present **slide F**. Remind students that In their prior work in *Magnets Unit*, they built a homemade speaker out of wire coils, a plastic cup, and a magnet, and this led to a series of additional investigations they pursued across the unit. Ask students to share examples of some of the cause-and-effect relationships they investigated in this previous unit with a partner. After 3 minutes, have students share some examples with the class.

Suggested prompt	Sample student responses
What are examples of some of the cause-and-effect relationships you investigated in this previous unit?	*How would changing the number of batteries affect the strength of the magnetic forces in the system?* *How would changing the distance between the wire coil and the magnet affect the forces between them?* *How did changing the position of the compass near a magnet affect the direction it pointed?* *How did flipping the direction of a battery affect the direction of the forces in the magnetic field around a wire coil?*

Additional Guidance

The examples that students share from *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)* will prime them to start thinking about distance forces and fields between objects in the next discussions. Don't explicitly identify this connection yet though.

Propose that we do some thought experiments with the variables we've already identified in this system. Display **slide G**. Give students three minutes to discuss the questions on the slide with a partner and then discuss these as a class.

Suggested prompts	Sample student responses
What if the Moon was a lot larger or smaller? Would that cause any change in how it moves (effect)?	*Accept all responses.*
What if the Moon was a lot closer to Earth or a lot further from Earth? Would that cause any change in how it moves (effect)?	*Accept all responses.*

Push on some extreme examples. Ask probing questions such as the following:

- *What if the Moon were really really close, like just a few hundred miles above the surface of Earth?*
- *What if the Moon were bigger and more massive than Earth?*

Some students are likely to suggest that the Moon would fall into Earth in the first case or Earth would fall into the Moon in the second case. Then ask follow-up questions, such as, *What would cause that? What would cause something far above Earth either to not fall toward it or to fall toward Earth?* Students are likely to raise the idea of gravity.

4. Connect to prior experiences.

6 MIN

Materials: None

Connect to examples from students's prior work in *Storms Unit*. Present **slide H**. Ask, *What ideas have we developed to help explain what causes water droplets or water crystals to fall to Earth as precipitation sometimes and not others?* Students should bring in ideas from *Storms Unit* related to things like the following:

- The droplets or crystals get too heavy for rising air to hold them up.
- The force of gravity pulling the water droplets or crystals down becomes greater than the lift forces (of moving air) from convection underneath them.

Problematize what we know about gravity. Say, *So we know gravity is a downward force that pulls things toward Earth when we are near the surface, and we also know that gravity is a force that pulls precipitation downward even when it's quite high above Earth's surface. How about a few miles up? Is there still gravity that high up? How about much farther away? Is there gravity near or on the Moon?* Accept all responses, but listen for students to debate where gravity forces are and are not located in the space between Earth and the Moon.

Connect to prior experiences in field based thinking. Say, *We've identified gravity as a type of force that acts at a distance. This feels really similar to the type of thinking you did with a different type of distance force, related to magnets. While gravity forces and magnetic forces might be different in some important ways, considering how far a distance force acts on objects and what objects it can act on was what you were doing when you were thinking about how to visualize a magnetic field between a wire coil and magnet.* Ask students to share some of the ways they visualized the magnetic field between a wire and magnet in *Unit 8.3: How can a magnet move another object without touching it? (Magnets Unit)*.

Suggested prompts	Sample student responses
What were some ways you visualized the magnetic field between a wire and magnet in Magnets Unit?	*We used arrows.* *We used compasses (and iron filings).*
What did you notice about the structure or strength of the magnetic field between a wire and magnet in your prior work?	*Accept all responses.*

Foreground field-based thinking. Say, *This thinking about fields seems potentially useful in this Earth-Moon system, since here again we now have some questions about how far away gravity forces affect objects relative to the position above Earth. We also have questions about whether there is gravity on or around the Moon. Gravity seems like an important mechanism to consider further when we start thinking about what might happen to the motion of the Moon around Earth if the Moon is closer or farther away from Earth or if it was more massive or less massive than it is now.*

5. Develop an initial model to explain the effect of changing the size or location of an orbiting object.

7 MIN

Materials: *What causes one solar system object to move around another one?*, science notebook



Use a model to develop an initial explanation. Say, *Why do we think the Moon moves around Earth the way it does? What is causing it to move that way rather than move a different way?* Display **slide I** and distribute *What causes one solar system object to move around another one?*. Encourage students to annotate the model if they wish and respond to the prompt in part A. After a few minutes, remind students to choose a question to record a prediction for and explain why you made the prediction you did.

Individually develop a model to explain the effect of changing size or location of an orbiting object in relation to another orbiting object. Display **slide J.** Have students develop an initial model using the prompt on the slide in their science notebook.

Assessment Opportunity

Building towards: 14.A Develop and revise an initial model of the Earth-Moon system to show the location, strength, and interaction of gravitational forces in the system.

What to look/listen for:

- Referencing gravity as an important force in the system
- Identifying gravity as a force that would tend to pull objects downward toward the surface of Earth (when near Earth's surface)
- Identifying where in the space above Earth and the Moon and between them gravitational forces would be found. This field-based thinking is similar to their prior work done in *Magnets Unit*.

What to do: It is not expected that students will have all of these ideas developed at this point. This is an important pre-assessment of student thinking before they engage in the second formative assessment toward the end of this lesson: 14.B.

6. Identify variables to change and measure in a simulation of gravity interactions between two objects.

6 MIN

Materials: *What causes one solar system object to move around another one?*, science notebook

Share examples of other pairs of objects in the solar system where one object orbits another. Display **slide K**. Ask students to share their answers with the class for part C from *What causes one solar system object to move around another one?*.

Suggested prompt	Sample student responses
What were some other pairs of objects that you picked for part C of your handout?	*Earth and the Sun* *the Sun and Venus* *Jupiter and its moons*

Suggested prompt	Sample student response
If a similar change was made in the system of these two objects, did you think it would cause the same effect as what you predicted in part B of your handout?	*Accept all responses.*

Motivate what we would need in a simulation of these systems to be able to model interactions between one object and another orbiting it. Emphasize that we have a really large system we want to experiment with to figure out why objects in our solar system move the way we do. Remind students that when scientists have systems they want to study that are too big or too small to study, they often use simulations to experiment with those systems.

Display **slide L.** Discuss the simulation specifications as a class using the prompts on the slide.

Suggested prompts	Sample student responses
What variables would we want to be able to manipulate or change in the system?	*the size or mass of the objects* *how far away the objects are from each other* *how fast one of the objects orbits the other* *Accept all responses, and do not worry if students do not suggest everything listed above.*
What interactions or outcomes would we want to be able to visualize or measure in that simulation?	*the gravitational forces* *how fast one of the objects orbits the other* *the path the orbiting object follows* *Accept all responses, and do not worry if students do not suggest everything listed above.*

Additional Guidance

You can support students here in making connections across units by reminding them of other computer interactives that simulated complex systems in previous units, such as the following:

- In *Storms Unit* you used a simulation that allowed you to visualize the speed of particles using color and lines of different length attached to the particles.
- In *Palm Oil Unit* you used a simulation that allowed you to visualize the movement of orangutans across a forest canopy, the amount of stored energy reserves they had in their bodies, and the available food sources in the forest.
- In *Sound Unit* you used a simulation that allowed you to visualize how the motion between the particles in a medium changed over time as the frequency and amplitude of vibrations of a sound source changed.

- In *Magnets Unit* you visualized the strength and direction of the forces on two magnets and the field surrounding them.

Say, *Tomorrow let's start right away using a simulation to test the question you identified on part B of your handout.* Collect *What causes one solar system object to move around another one?* before students leave for the day.

End of day 1

7. Preview the interactives and make predictions.

7 MIN

Materials: *Simulating a Two-Object System*, *What causes one solar system object to move around another one?*, computer, projector, Computer Interactive: Exploring Orbits Fixed Perspective (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Distribute the completed copies of *What causes one solar system object to move around another one?* back to students. Ask them to add these to their notebook.

Introduce the two-object system computer interactives. Present **slide M**. Say, *we reviewed the things we would want to change in a simulation about the objects in a system to explore the patterns we noticed in the solar system. And you identified the question you want to investigate with such a simulation on part B of* What causes one solar system object to move around another one?*, which you now have in your notebook. Let's orient ourselves to the interactive we are going to use to investigate those questions.*

You can run the interactive for students to demonstrate it (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), or you can use the prerecorded video 8.4 Lesson 14 Exploring Orbits Introduction (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Using **slides N-R**, briefly run the model with the default settings it loads with. Point out the gravity forces on each object, visualized with red arrows, and the orbit pathway of the smaller object. Pause the model, and show students how to change each of the following variables: (1) the mass of the smaller object, (2) the distance of the objects, and (3) the speed of the smaller object. Explain that they will need to press SETUP to initialize those changes, and then press GO/PAUSE to run the model, but be cautious not to go any further, as this runs the risk of completing the investigation for students before they have a chance to explore it.

Make predictions. Present **slide S**. Distribute *Simulating a Two-Object System* to students. Ask students to complete parts 1 and 2.

8. Investigate the interactions between two objects.

16 MIN

Materials: *Simulating a Two-Object System*, Computer Interactive: Exploring Orbits Fixed Perspective (See the **Online Resources Guide** for a link to these items. **www.coreknowledge.org/cksci-online-resources**)

Work in groups to explore the interactive. Project **slide T**. Group students so that each group has access to one computer with the interactive. Give student groups 3 to 5 minutes to explore the simulation in an open-ended way with the goal of testing their predictions. Say, *While the handout provides you with some specific guidance for recording and analyzing data from the interactive, take the next few minutes to play with the simulation in an open-ended way to see what the simulation does and to consider ways that it might help you answer some of the student's questions. As you play with the simulation, talk about what you notice with your small group, involving everyone in the conversation.*

Additional Guidance

Students may make several connections to prior knowledge and previous units as they explore the simulation. Support students in making these connections but also bear in mind that the goal of the simulation is to uncover the factors that affect the objects orbit, so other connections and ideas are ancillary. Examples of connections that may be made include the following:

- the synchronous spin and orbit of the object 2 around object 1
- the impact of the gravitational pull of the object 2 on object 1
- the elliptical nature of orbits and the relationship among the distance of an orbiting object, the gravity force, and the speed of the object
- the relationship between the gravity force and other distance forces



Use the interactive to complete *Simulating a Two-Object System*. Ask students to turn their focus to completing the data table on the handout. As the students use the simulation in small groups to complete *Simulating a Two-Object System*, circulate the room to provide technical assistance, push student thinking forward, and assess and respond to student's thinking. If time permits, students can go to interactive in their web browser to load this new simulation and continue your investigations. This simulation lets you zoom out further in your perspective.

Assessment Opportunity

Building towards: 14.B Use a simulation of a two-object system to produce data that can be analyzed to identify patterns to determine how changes in the mass or distance between the objects in the system affects the strength of gravitational forces between those objects in space.

What to look/listen for: Look for students to identify the following relationships:

- If the force of gravity between the two objects decreases (mass decreases or distance between objects increases) or the outer object moves faster, the outer object will fly away.
- If the force of gravity between the two objects increases (mass increases or distance between objects decreases) or the outer object moves too slowly, the outer object will crash into the inner object.

What to do: With reference to the computer interactive, ask students to show you what they can manipulate in the system. Ask them what was interesting about their object or why they chose it to be represented in the interactive. Ask students what each object and component represents in the system. Reinforce that these manipulations are not possible in the real world. Use hypotheticals ("What if the Moon …") to help students link simulation results to the actual orbit of the Moon or another object of their choosing. If students are still struggling to identify the independent and dependent variables, ask them to tell you what they changed in the system and what the effect was on their objects. If students need additional probing to identify independent and dependent variables, ask them what they kept constant or did not change in the system.

In the last 3 minutes available, have students close the interactive and discuss with their small group the making-sense questions on *Simulating a Two-Object System*.

9. Build understanding about the interactions of gravity forces between two objects. 15 MIN

Materials: science notebook, *Simulating a Two-Object System*, chart paper, markers, Exploring Orbits simulations (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Discuss the key take-aways from the simulation. Project **slide U**. Lead a Building Understandings Discussion to help the whole class summarize key ideas from the interactive.

Key Ideas

Purpose of this discussion: Identify the factors that affect the orbital motion of the one object around another and, by extension, orbital motion in general.

Listen for these ideas:

- The strength of the gravity force on an orbiting object and the speed of the object affect its orbit.
- The mass of an object interacting with another object affects the strength of the gravity force on both objects.
- The distance between two interacting objects affects the strength of the gravity force pair on the objects.

Additional Guidance

This is a prime opportunity to use the language and connections of your students to help make sense of science ideas and generalize a model. Try to use the object names your students use synonymously with outer or inner objects based on the objects positions to each other.

After one student speaks, ask another group if they noticed something similar for their objects, then ask them to describe their objects and the interactions they witnessed in the simulation. If students struggle with this, you can always return to the stable orbit of the Earth-Moon system set as the default in the simulation. Do not hesitate to bring the simulation back up on the screen and have students come up to the screen and tell you what is happening in the system. They can have you manipulate the variables to make stronger points.

As students share their ideas, encourage them to show their thinking by pointing out what they mean on the models. Potential questions to support this idea sharing include the following:

- Can anyone restate what ___ just shared in your own words to be sure we understand?
- Did anyone else talk about that with their partner?
- I'm not sure what you mean by that. Please help us understand your thinking by showing us on the model.
- Does everyone agree with that point? Is there anyone who doesn't agree?

Use the following prompts to elicit student ideas about how to get the outer object out of a stable orbit.

Suggested prompts	Sample student responses	Follow-up questions
What sort of things caused the object A to fly out of a stable orbit of B?	*When the speed of object B was too high.* *When the mass of the object was too small.* *When its distance was too far away.*	*Why didn't gravity forces pull it back into a stable orbit?*
What sort of thing caused object B to collide with object A?	*When it was moving too slow.* *When it was too massive.* *When they got too close to one another.*	*How did gravity forces change in these conditions to contribute to this outcome?*

Say, *Increasing the mass of the outer object and decreasing the distance from objects both had the same effect of the outer object crashing. That's really interesting.*

Suggested prompts	Sample student responses	Follow-up questions
How can you use gravity to explain why changing these two things that seem pretty different have the same effect?	*They both made the gravity forces bigger.*	*Did everyone else notice the gravity forces getting bigger when you increase the mass of the outer object (object B) and decrease the distance between it and object A?*
How are the gravity forces on the outer object (object B) and the gravity forces on the inner object (object A) in this simulation related?	*They were the same strength but in opposite directions.*	*Are there any other examples of this that we can remember?*
How does the strength of the gravity force impact the motion of the outer object (object B)?	*If the gravity force is very strong, the outer object crashes. If the gravity force is very weak, the outer object seems to fly away from Earth.*	*Based on what you know about how forces affect an object's motion, why do these observations make sense?*
How does the strength of the gravity force impact the motion of the inner object (object A)?	*Stronger forces caused it to wobble more.*	*What does this predict we should see happening to things like Earth as the Moon orbits around it.*

Say, *So increasing mass and decreasing distance make the gravity forces stronger. But you mentioned speed as well as something that made the object's collide with each other.*

Suggested prompts	Sample student responses
Did higher or lower speed increase the gravity forces?	*No, but if the outer object moves very slow, it crashes into the inner object.*
What happened when you increased the speed?	*If the outer object moves very fast, it flies away from the inner object.*

Co-construct a poster summarizing the factors that keep the objects in orbit. Label a piece of chart paper "Factors that Affect the Orbit".

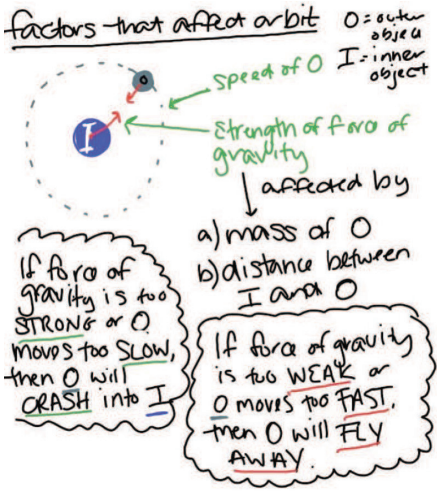
Suggested prompt	Sample student response	Follow-up questions
What can we conclude about the factors that make the movement of one object around another and not something else in the solar system? What questions do we still have?	*The speed of the object and the strength of the gravity force acting on it keep the object in orbit.*	*Why do you think these factors are important? Let's think of an example: If the Moon orbits Earth because it has the right speed and gravity force acting on it, could other objects with the right combination of speed and force acting on them also orbit Earth?*

Sketch the factors. As you have this discussion, sketch on the poster an image similar to the simulation, including the orbital path, speed lines, and gravity force arrows. You can do this for the Moon and Earth and/or for any two objects in the solar system. As they come up in the discussion, write to the side of the sketch the two factors that affect the orbit:

"1. the speed of the orbiting object"

"2. the strength of the gravity force on the orbiting object"

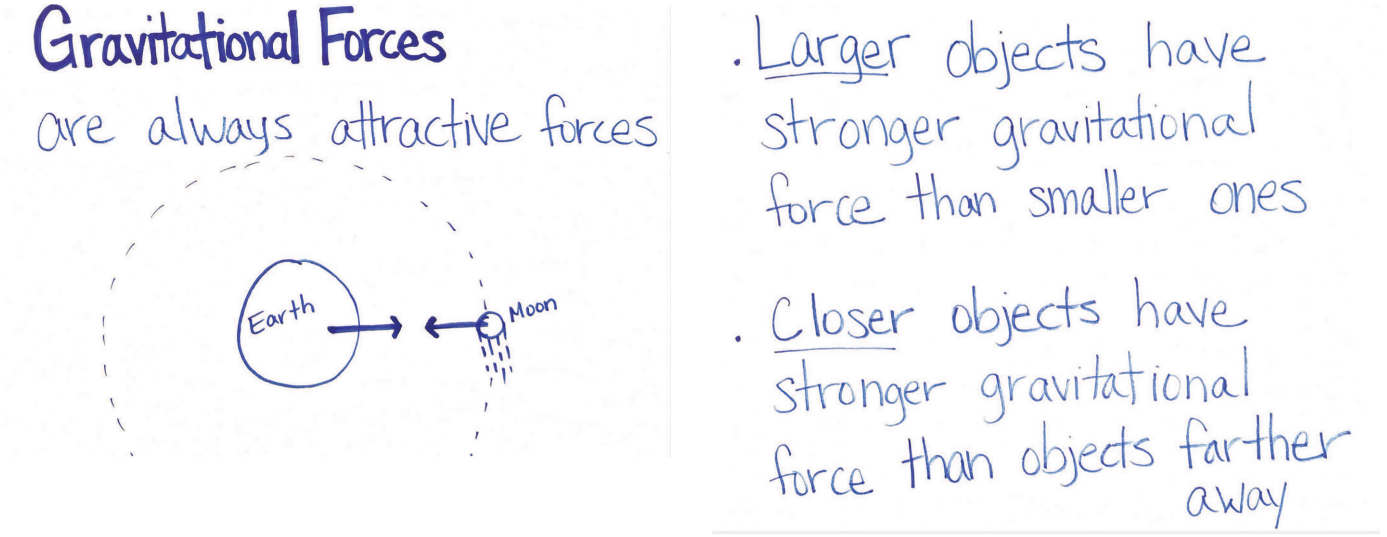
Draw an arrow pointing from each factor to the element of the simulation it mentions. Draw an arrow pointing down from "2. the strength of gravity force on object O (e.g., the Moon)" and label it "This strength is affected by". Below that arrow write "a. the mass of object O (e.g., the Moon) and the mass of object I (e.g., Earth)" and "b. the distance from object I (e.g., Earth) to object O (e.g., the Moon)". Write a summary statement at the bottom, such as "If the force of gravity on object O (e.g., the Moon) is too strong or object O moves too slowly, it will collide with object I!" or "If the force of gravity on object O is too weak or object O moves too quickly, it will fly away!" See the accompanying image for an example.



Add gravitational forces to your Word Wall. If you have not done so already, if it did not come up earlier, as you are sketching the factors, begin to develop a working definition of *gravitational forces* as *always attractive forces.* See the sample image shown on the following page.

As the discussion continues, you can add clarifying statements, such as those below about the mass and distance.

Have students tape *Simulating a Two-Object System* into their science notebook.



10. Navigation

6 MIN

Materials: science notebook, DQB

Consider the state of the system at different time scales (future and past). Say, *We used the simulation to run experiments where the objects in the system moved through space, and in some cases followed a repeating pattern of motion through an orbit. The orbit of the Moon around Earth takes about 29 days, and the orbit of Earth around the Sun takes about 365 days. In the simulation we could visualize multiple orbits in seconds rather than days. Studying this system over a compressed timescale helped us see interactions we might not be able to visualize as easily on a regular time scale. Let us consider the structure and motion of the object in our solar system over much longer time scales, make some predictions, and then think about what questions that raises for us. We will share those questions next time and consider how we might investigate them further.*

Display **slide** V. Read through the bullet points on the slide and give students the remaining time to record responses to the three prompts on the slide in their notebooks.

If time permits, have students start sharing out the questions they recorded at the end of this lesson. If time is short, use the start of the next lesson to have students share these questions. Look for student questions such as:

- What would happen if the orbit completely rotated?
- How did some objects get into orbit?
- Can stars orbit planets?
- How do objects end up orbiting celestial objects like the Sun or Earth?
- What speed does the Moon move at now? Was it the same as in the past?

- How did this start happening?
- What would happen if all force and gravity was gone from space completely?
- How do objects begin to orbit?
- Have orbits always been this way?

Additional Guidance

The ideas about gravitational forces and interactions between different orbiting objects will continue to be built over the final three lessons of the unit. Students should understand how changing the size of an object, distance between objects, or speed of an object affects the orbits. In the next lesson, students use these concepts to explain the formation of the solar system.

LESSON 15

How did the solar system get to be the way it is today?

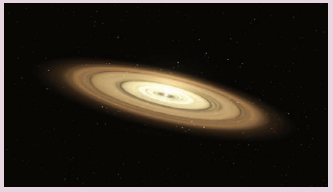
Previous Lesson

We shared initial ideas about patterns of motion in the solar system, which led us to conduct a cause-and-effect thought experiment around those patterns. We used a simulation to investigate how changing distance and size affects an object's orbit around another object in the solar system. We built understanding as a class about the relationship between size, distance, and the strength of the force of gravity.

This Lesson

Investigation

1 DAY



NASA

We analyze images of craters on the surface of Mercury and two moons. We watch a video showing the results of a computer simulation that models the formation of the solar system. We develop storyboards to support the claim that the solar system was formed from a disk of gas and dust, drawn together by gravity. We build a class consensus storyboard model of the formation of the solar system.

Next Lesson

We will look at a photo taken by the Hubble telescope of the space between stars, showing what we think might be more stars or maybe something else entirely. We will learn that these are galaxies and then watch the Tour of the Universe to visualize how scientists model the universe.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

15.A. Develop and map evidence from written and media sources to support the claim that the solar system formed from a disk of gas and dust, drawn together by gravity that was once chaotic but has become more stable over time.

What Students Will Figure Out

- The Sun formed in the center of a disk of gas.
- The matter in the disk of gas began to collect to form bigger clumps of matter (e.g., pebbles) due to gravity.
- These pebbles collided and clumped together to form smaller planets.
- The smaller planets collided many times over several millions of years, resulting in the creation of larger planets, asteroids, and comets.
- The collisions became less common as objects in the solar system as the objects had stable orbits.

Lesson 15 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	7 min	**NAVIGATION** Elicit student ideas and questions about stability and change in our solar system.	A-C	sticky notes, marker
2	5 min	**ANALYZE AND INTERPRET DATA** Analyze photographs of the Moon, Mimas, and Mercury.	D-I	
3	10 min	**OBSERVE A COMPUTER MODEL OF THE FORMATION OF THE SOLAR SYSTEM** Students watch a video showing results of a computer simulation (model) of the formation of the solar system.	J	8.4 Lesson 15 Simulating Solar System Formation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	8 min	**CREATE COMIC BOOK STORYBOARDS SHOWING THE FORMATION OF THE SOLAR SYSTEM** Students individually develop a step-by-step storyboard illustrating the formation of the solar system.	K	*Comic Book Storyboard Showing the Formation of the Solar System*
5	10 min	**DEVELOP CLASS CONSENSUS MODEL FOR THE FORMATION OF THE SOLAR SYSTEM** Move into a Scientists Circle to share storyboards. The class remains in a Scientists Circle to develop a class consensus model for the formation of the solar system.	L-M	*Comic Book Storyboard Showing the Formation of the Solar System,* "Class consensus storyboard for the formation of the solar system" poster, markers
6	5 min	**NAVIGATION** Take stock of questions and consider what else might be beyond our solar system.	N-O	DQB, Ideas for Investigations poster

End of day 1

Lesson 15 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • sticky notes • marker • *Comic Book Storyboard Showing the Formation of the Solar System*		• 8.4 Lesson 15 Simulating Solar System Formation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • "Class consensus storyboard for the formation of the solar system" poster • markers • DQB • Ideas for Investigations poster

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Create a poster titled "Class consensus storyboard for the formation of the solar system" in the style of a comic book storyboard, similar to that seen on *Comic Book Storyboard Showing the Formation of the Solar System.*

Test the Simulating Solar System Formation video at 8.4 Lesson 15 Simulating Solar System Formation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Be sure you have materials ready to add the following word to the Word Wall and/or a personal glossary: *accretion.* Do **not** post this on the Wall until after your class has developed a shared understanding of its meaning.

Lesson 15 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will map back evidence from prior lessons to support a computer model video of the formation of the solar system. It is important to spend time relating how what we see today helps us understand what has happened in the past. In the next few lessons, students continue with this thinking as a way to further support how scientists create models based on our current understanding and similar phenomena elsewhere.

Where We Are NOT Going

We are not specifically getting into the exact timeline of the formation of the solar system. Students may want to put exact numbers of years on their comic book storyboards, but that is not a focus of the activity. It is more important that students realize that this took a very long time and that stability of the solar system was not immediate but was incremental. In high school, students begin to explore geologic timescales using more precise measurements.

LEARNING PLAN FOR LESSON 15

1. Navigation

7 MIN

Materials: science notebook, sticky notes, marker

Elicit student ideas about the solar system. Present **slide** A. Say, *Let's consider some of your ideas: How would the structure of our solar system and the patterns of motion that objects follow now compare to their motion in the future?* Take a class poll about the question on the slide: *Do you think all the objects in our solar system will remain in these orbits far into the future?* Anticipate competing predictions.

Foreground stability and change. Say, *Some of us are making predictions that the patterns of motion of the objects in our solar system will remain stable in the future, while others of us are predicting they will change. Thinking about whether a system will remain stable or change over time is a useful crosscutting concept for trying to understand what might cause that stability or what might cause that change.*

Distribute a sticky note and marker to each student. Present **slide B.** *Say, Let's use that thinking to start considering why our solar system is organized into a structure that has objects following relatively stable orbits.*

Suggested prompt	Sample student response
Based on what we have figured out so far about solar system objects and their interactions, what do you think might have happened that could help explain why our solar system is organized the way it is today?	*Accept all answers.*

Ask students to review the questions they recorded last time and pick one, or make a new one that is most compelling to them now and add it to a sticky note, with their initials on it, and put it on the front of their science notebook. Emphasize that we will see if we made progress on these questions by the end of the lesson.

Consider possible sources of evidence. Present **slide C.** Give students a couple of minutes to discuss the question with a partner and then discuss the responses as a class.

Suggested prompt	Sample student responses
What are some sources of data that scientists might be able to use to figure out what the solar system was like in the past?	*stories people have passed down of what they observed* *journal entries or written records of what people observed* *cave drawings*

After students have shared ideas, say, *These are some interesting ideas. But, how are we going to investigate the history of the solar system if people weren't around to document it? Humans have been around for a couple hundred thousand years, but we know from the work we did in Unit 6.4: What causes Earth's surface to change? (Everest Unit) in trying to figure out*

why some mountains are growing and some are shrinking that the Earth has been around for many hundreds of millions of years.

Emphasize that to go further back in time to figure out what the solar system was like many millions of years ago requires additional sources of data. Explain that one important source of data for this has been photographs of the surfaces of moons and planets that we have taken with spacecraft that have gotten closer to them. Say, Let's *take a look at a few photographs that these spacecraft have taken of these surfaces and see what clues they give us about what our solar system might have been like in the past.*

Additional Guidance

Students' prior work in *Unit 6.4: What causes Earth's surface to change? (Everest Unit)* provides them evidence for the Earth having been around for millions of years, but it does not yet provide them evidence for the Earth being "at least X years old" and works with the assumption that the Earth did not exist at some point in the past, which precludes the possibility that it has always existed. The subsequent activities will help students reason out a line of evidence and mechanism for the formation of the planets (including Earth) at some point in the past. At that point, it will make sense to students to start referring to the questions, ideas, and assumptions about the formation of the Earth as well as the rest of the solar system at some point even further back in time than when the continents were in very different positions than they are today (hundreds millions of years ago). After watching that video, it is not important that students know the current best estimate of the age of the solar system and the age of the Earth (~4.5 to 4.6 billion years old).

2. Analyze and interpret data.

5 MIN

Materials: science notebook

Analyze images of the Moon, Mimas, and Mercury. Present **slide D** and then present **slide E.** Give students half a minute to study the photographs on each of the slides.

Interpret data from images to make connections to the past. Present **slide F.**

Suggested prompt	Sample student responses
What clues do photographs like this provide us about what the solar system might have been like in the past?	*They are all pockmarked.* *They all have craters on them.* *They must have gotten hit by meteors long ago.* *They must have collided with other objects in the past.*

Ask a few students to show with their hands what they picture happens when a meteor collides with a moon or planet and makes a crater. Explain that on Earth we also sometimes see meteors, but rarely do they make it to the surface because they heat up as they move through our atmosphere and break apart before leaving a crater in the ground. But whether the meteor breaks up into a lot of little pieces or makes it to the surface relatively intact, the matter that made up that object has now been added to Earth. Present **slide G.**

Suggested prompt	Sample student response
If meteor impacts tend to add additional matter to planets and moons, how would the size of all the planets and moons long ago compare to their size today?	*They must have been smaller long ago than they are today.*

Say, *If this tells us that the planets and moons would have been smaller long ago, then how much smaller would they have been really long ago? And how many more objects might have been in our solar system long ago, before these collisions occurred, than there are now? To help answer these questions, scientists have sent additional spacecraft to get more data from smaller objects moving through our solar system, like comets and asteroids.*

Examine comet and asteroid data. Display **slides H** and **I.** Point out to students the composition and size of these objects and that the asteroid is a loose pile of small pieces of material (rubble) held together by weak gravity.

Say, *The composition of these objects and the smaller pieces they are made of provided scientists with strong lines of evidence for creating computer simulations to test their ideas about what the solar system* was *like billions of years ago.*

3. Observe a computer model of the formation of the solar system. 10 MIN

Materials: science notebook, 8.4 Lesson 15 Simulating Solar System Formation (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Connect to the interactions included in prior simulations students used. Explain that these simulations use the same basic rules in the model for how mass, distance, and the force of gravity between any two pieces of matter influence each other's motion, but that instead of including only two pieces of matter or two objects at a time, they include many more pieces of matter, sometimes billions of pieces of matter. Explain that such simulations often take a large number of computers and time to run because of the amount of calculations required for all of these interactions going on in the model. Emphasize that these simulations still help scientists run virtual experiments over timescales they can't directly observe, which allows them to test whether their model assumptions about what was happening in the solar system long ago can accurately predict why it is structured the way it is today. *Say, Let's get ready to examine a short video that will summarize some of what these spacecraft discovered as well as showing us the results of these computer simulations.*

Observe a computer model of the origin of our solar system. Present **slide J.** Have students add a table to their science notebooks to record the following while watching the computer model:

- What I see...
- What I think...
- How has my thinking changed...

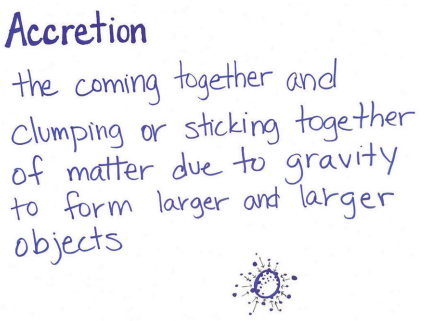
Say, *I am going to play a video showing a computer model of the formation of the solar system. At the beginning of the video, it flies around our solar system before going into the computer model of the formation. As you watch the video, record in your science notebook: what you see, what you think, and how your thinking has changed.* Play the video (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) without any sound and

with closed captioning off. Have students record their responses to the three prompts in their notebooks. Ask a few students to share what they saw, what they think, and how their thinking has changed.

Say, *I am going to play this video a second time, this time with the sound on. Add to your responses from watching the video the first time without sound.*

Play the video a second time with the sound on and closed captioning on. Have students record additional responses to the three prompts in their notebooks. Ask a few students to share what they saw, what they think, and how their thinking has changed.

Clarify the meaning of *accretion*. Students are likely to ask what the word *accretion* means, having encountered it in the video. Provide students with the definition of this new word and add it to the Word Wall. *Accretion* means the coming together and clumping and sticking together of matter due to gravity to form larger and larger objects. Add this definition to the Word Wall.



4. Create comic book storyboards showing the formation of the solar system.

8 MIN

Materials: *Comic Book Storyboard Showing the Formation of the Solar System*

Develop explanations for the formation of the solar system. Present **slide** K and handout *Comic Book Storyboard Showing the Formation of the Solar System*. Explain to students that they will develop a storyboard to illustrate their explanations about how the solar system formed based on evidence from the computer model and prior investigations. Tell students that each frame of the storyboard should illustrate and explain the step-by-step process of how our solar system was formed. Give students about 8 minutes to develop their storyboards.

Assessment Opportunity

Building towards: 15.A.1 Develop and map evidence from written and media sources to support the claim that the solar system formed from a disk of gas and dust, drawn together by gravity that was once chaotic but has become more stable over time.

What to look/listen for:

- Beginning of the solar system was a collection of gas and dust particles in a disk going around our Sun.
- The particles of this gas and dust were drawn together by gravity, which formed bigger pebbles and rocks.
- These were drawn together to form even bigger clumps of matter; this process continued, forming asteroids, moons, and smaller planets.
- Many smaller planets collided to form larger planets over time.
- Some objects were thrown out of the solar system in this process.
- Over millions and millions of years, the collisions became less common and the solar system stabilized to the form it is today.

What to do: If students are struggling to identify the steps, stress that at this point they may not be sure of the exact order or number of steps, but it is important that they get their ideas out. Refer them back to the video of the computer model and prior investigations from previous lessons about the solar system. If students do not show evidence for the steps in their storyboard, prompt them to provide information from both the video of the computer model and prior investigations to support the information presented in their storyboards.

5. Develop class consensus model for the formation of the solar system.

10 MIN

Materials: *Comic Book Storyboard Showing the Formation of the Solar System,* "Class consensus storyboard for the formation of the solar system" poster, markers

Get into a Scientists Circle to share storyboards. Present **slide L.** Have students get into a Scientists Circle with their solar system formation storyboards. Encourage students to ask each other clarifying questions and to record specific places on their storyboards where they have agreement with their classmates.

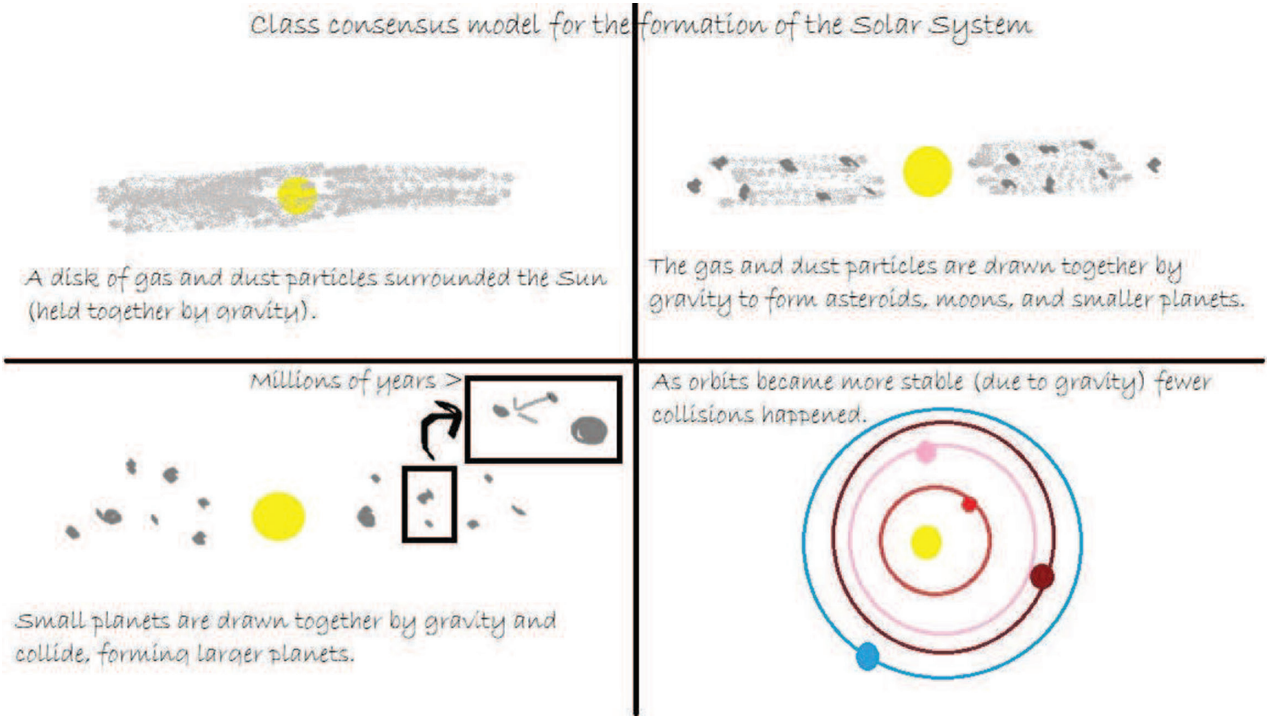
Develop a class consensus model for the formation of the solar system. Present **slide M.** Ask students to share which ideas there seemed to be consensus of during the storyboard sharing and the evidence to support the idea.



Additional Guidance

Students may struggle to identify pieces of evidence to support the different steps in the comic book storyboard of the formation of the solar system. Prompt them to think about how the images and structures they examined in the previous lessons could provide evidence of the changes the solar system underwent. For example, if students struggle to identify evidence from earlier lessons to support the step that the disk of gas and dust collapsed, say, *Think back to our previous lesson and where the different objects in the solar system are located in space. Are they located at different levels* (demonstrate by stacking your hands), *or are they all at the same level* (demonstrate by putting your hands side-by-side)? Look for students to say they are at the same level. *How could them being at the same level be evidence for the collapse of the cloud of gas and dust?* Look for students to say because everything is at the same level, it had to have collapsed because if it didn't, everything would be stacked.

Add those ideas to the "Class consensus model for the formation of the solar system" storyboard poster. A sample poster is shown below.



Have students copy the class consensus model storyboard into their science notebooks.

Assessment Opportunity

Building towards: 15.A.2 Develop and map evidence from written and media sources to support the claim that the solar system formed from a disk of gas and dust, drawn together by gravity that was once chaotic but has become more stable over time.

What to look/listen for:

- The solar system started as a disk of gas and dust drawn together by gravity.
- The Sun formed in the center of the disk, and the matter that was left over began to collect to form small planets.
- The small planets collided many times over several millions of years, resulting in the creation of larger planets, asteroids, and comets.
- The collisions became less common as objects in the solar system as the objects had stable orbits.

What to do: Prompt students to go back to the information given in the computer model and what they have figured out in prior lessons as evidence to support the class consensus step-by-step storyboard.

6. Navigation

5 MIN

Materials: science notebook, DQB, Ideas for Investigations poster

Take stock of questions. Present **slide N.** Ask students to look back at the sticky note question they had written at the start of the lesson and to put a check mark on it if they feel we made progress on it. Take a show of hands of students who felt the lesson helped partially answer their question. Emphasize that you want to collect these questions so we can keep track of those we are making progress on as well as ones that we still need to answer. Suggest that the more we figure out, the more questions we should have.

Collect students sticky notes to add to the Driving Question Board. This should include both checked and unchecked questions.

Consider space beyond our solar system. Say, *Since we've talked a lot today about how the star is at the center of our solar system and today we figure out how our solar system formed, this may only have helped make progress on some of the questions you had about our solar system, but we may still have others about things beyond our solar system. In order to answer those questions, we need to start considering what else, if anything might be out there.*

Present **slide O**. Discuss the related question on the slide as a class.

Suggested prompts	Sample student responses
So, If we want to see far beyond our solar system, what might be some limitations in seeing stuff really, really far away when we try to make observations only with our unaided eyes?	*It might be too small or too far away to see.* *It might not be bright enough.* *There might be stuff blocking it or in the way (clouds, the atmosphere, etc.)*
I hear you saying it would be hard to see with just our eyes, but what would we see if we used really powerful tools like telescopes to look even farther into space. What are some things we might expect to see that we can't see with our unaided eyes?	*Stars?* *Other systems?* *More planets?* *Galaxies?*
Let's say we pointed a telescope at a spot in space that looks relatively empty to our unaided eyes. Would you expect there to be something there that might show up with a telescope? If so, what? If not, why?	*more matter* *maybe gas* *maybe planets* *maybe other stuff (galaxies, black holes)* *maybe it's empty because there is a lot of empty space in our solar system*

Say, *It sounds like we might want to look at the sky again but with more than just our unaided eyes, and this time look in some different places in space where it looks relatively empty.*

LESSON 16

What patterns and phenomena are beyond our solar system that we cannot see with just our eyes?

Previous Lesson

We analyzed images of craters and watched a video showing the results of a computer simulation that models the formation of the solar system. We developed storyboards to support the claim that the solar system was formed from a disk of gas and dust, drawn together by gravity. We built a class consensus storyboard model of the formation of the solar system.

This Lesson

Investigation

1 DAY



NASA, ESA, G. Illingworth, D. Magee, and P. Oesch (University of California, Santa Cruz), R. Bouwens (Leiden University), and the HUDF09 Team

We make noticings and wonderings from a photo taken by the Hubble telescope of the space between stars, showing what we think might be more stars or maybe something else entirely. We learn that these are galaxies, islands of stars much like the ones we see in the sky. We watch the Tour of the Universe to visualize how scientists model the universe at various scales. We notice that the universe appears to be organized into systems held together by gravity, separated by vast emptiness.

Next Lesson

We will make a classroom consensus model at various scales of how gravity organizes the universe. We will return to the DQB to take stock of how far we have come in this unit and then reflect on the unit and Earth's place in the universe.

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

16.A Compare and critique two arguments emphasizing the same evidence (images of galaxies) about the organization of systems in space.

16.B Obtain and synthesize information across multiple sources about the organization of space systems in our universe from the human scale to the galactic scale.

What Students Will Figure Out

- Earth orbits the Sun, making the Sun and Earth part of our solar system, along with other planets, asteroids, comets, and so forth.
- Moons orbit planets, creating subsystems of the solar system.
- Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
- Gravity appears to determine this organization because in the places where there is stuff, that stuff is held together by gravity.

Lesson 16 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	5 min	**NAVIGATION: LOOKING BEYOND THE STARS** Recall that we wanted to see what was beyond the solar system with a telescope. Notice and wonder about the Hubble Deep Field photo.	A–B	*Hubble eXtreme Deep Field*
2	10 min	**INTRODUCE THE GREAT DEBATE IN ASTRONOMY** Introduce the Shapley-Curtis Great Debate in astronomy about whether galaxies are clouds of dust and gas or islands of stars.	C-D	*The Great Debate*
3	10 min	**WATCH A TOUR OF THE UNIVERSE** Watch the video *A Tour of the Universe.*	E	*Tour of the Universe,* 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
4	15 min	**BUILD UNDERSTANDINGS ABOUT GALAXIES** Hold a Building Understandings Discussion to develop the idea that Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.	F–G	*The Great Debate,* chart paper, markers
5	5 min	**NAVIGATION** Consider which questions we answered today and how they connect to life on Earth.	H	

End of day 1

Lesson 16 • Materials List

	per student	per group	per class
Lesson materials Student Procedure Guide  Student Work Pages 	• science notebook • *Hubble eXtreme Deep Field* • *The Great Debate* • *Tour of the Universe*		• 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) • chart paper • markers

Materials preparation (45 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Test the Tour of the Universe video at 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). Make sure you can hear the audio.

Online Resources 

Prepare chart paper for posters. The posters you will make in this lesson are as follows:

- Objects that Interact through Gravity
- Classroom Consensus Model for the Universe

Be sure you have materials ready to add the following words to the Word Wall: *galaxy* and *universe*. Do not post these words on the wall until after your class has developed a shared understanding of their meanings.

Lesson 16 • Where We Are Going and NOT Going

Where We Are Going

In this lesson, students will develop the last element of the DCIs associated with MS-ESS1-2: Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Where We Are NOT Going

The existence of galaxy clusters held together by gravity is as far as students will go into cosmology in middle school. We will not develop ideas about the large-scale structure of the universe, the cosmic microwave background, the Big Bang, or nucleogenesis.

LEARNING PLAN FOR LESSON 16

1. Navigation: Looking Beyond the Stars

5 MIN

Materials: science notebook, *Hubble eXtreme Deep Field*

Briefly orient students to where we are. Project **slide** A. Ask, *What were we wondering about at the end of the previous lesson?* Look for students to suggest that we have explained a lot of patterns and connections we could see with our unaided eyes but were wondering what was beyond our solar system and what was out there that we cannot see.

Notice and wonder about the blobs in Hubble Deep Field. Say, *Scientists have also wondered about the same sort of thing and have kept designing more powerful telescopes to try to find out what else is out there beyond the stars we can see with our unaided eyes. I found one source of photos taken using one of the most powerful telescopes, the Hubble Space Telescope. The photo you will see on the next slide was what they* saw *when they pointed the telescope at a space in between the stars, a tiny patch of the sky that looks to us to be about the size of the head of a pin held at arm's length.*

Display **slide B,** which shows the Hubble Deep Field. You could also hand out *Hubble eXtreme Deep Field* if you can print in high-resolution color. Briefly elicit student noticings and wonderings about the photo. Look for students to suggest that the images are stars or star systems. Some students might suggest that they are galaxies. Ask those students, *What do you mean by "galaxy"? Can you explain that further?*

2. Introduce the great debate in astronomy.

10 MIN

Materials: *The Great Debate*

Introduce the Great Debate. Say, *We have a couple of ideas about what these blobs in the photo might be. Scientists have argued over what* was *beyond the stars for a long time as well. Some scientists thought that what we* saw *in the sky* was *everything in existence. This led them to conclude that our solar system* was *centered around a star that* was *one star out of many grouped together and that all of these objects were like clusters or an island, beyond which there was a vast sea of nothingness. Other scientists suggested that if this were true, then another possibility to consider was that our solar system and the stars we can see with our unaided eyes was indeed like an island or cluster of stars, but that there must be other islands of stars out there too, but maybe much, much farther away from the one our solar system was a part of.*

Project **slide C** and pass out *The Great Debate*.

Give students three minutes to read on their own, and then ask one or two students to read aloud the text on the handout. Then elicit student ideas about the prompts at the bottom of the handout:



- How did Shapley's model for the universe explain the evidence he had at the time? How did Curtis's model for the universe explain that same evidence?
- What would you do to resolve this debate? What kind of data would you collect, and how?

Assessment Opportunity

Building towards: 16.A Compare and critique two arguments emphasizing the same evidence (images of galaxies) about the organization of systems in space.

What to look/listen for: Look for students to notice that both models explain the evidence in different ways. Also look for students to seek out data related to how far away things are in space.

What to do: Highlight student ideas about using telescopes to look more closely or measuring the distance to stars or blobs somehow.

Project **slide D**. Say, *Let us observe the image on the slide. In the 1920s, scientists used telescopes to confirm that there are islands of stars out there. They named the islands of stars galaxies. This allowed them to build a model for the known universe. Looking at this image and using what you have figured out so far about gravity and objects in space, who do you predict had the correct model, Shapley or Curtis?* Accept all responses and then say, let's gather some more information about the organization of systems in space.

Alternate Activity

Extension Opportunity: If you have students who are interested in citizen science and finding out more about galaxies, you can suggest that they become involved in a crowdsourced astronomy project that invites people to assist in the classification of large numbers of galaxies. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

3. Watch A Tour of the Universe. 10 MIN

Materials: *Tour of the Universe,* 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Organize students for the Turn and Talk activity. Display **slide E**. Organize students in groups of 4 to watch the video. Assign each student in the group a number. When students Turn and Talk during the video, use the different combinations of students so that they don't talk with the same person each time.

Watch *A Tour of the Universe* from the California Academy of Science. Pass out *Tour of the Universe.* Begin playing 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**). If time permits, have students play the video twice. First, have them just watch it without doing any writing. Then on the second time through, have them pause at each travel time to turn and talk with a partner in their group. They should record their notice and wonders about the objects and scale in view on the handout.

4. Build understandings about galaxies.

15 MIN

Materials: *The Great Debate,* chart paper, markers



Discuss each of the Turn and Talk prompts as a class. Project slide F, which lists all the prompts. For each prompt, direct students to Turn and Talk with a different partner from their group by their numbers, for instance, students 1+3 and 2+4 can talk first. Then discuss each prompt with the whole class before another Turn and Talk for the next prompt.

Suggested prompts	Sample student responses
Why do you think scientists choose to make the icy Kuiper Belt objects the boundary of our solar system? Why not end the solar system at Neptune or extend it out to include other stars?	*All of the things in the solar system interact with each other because of gravity.*
Does the shape of the galaxy remind you of any other systems that we have studied so far? If so, how? What do you think that means about how the parts of the Milky Way system interact?	*The galaxy is a flat disk, like our solar system. Maybe the parts are also orbiting something at the center of the galaxy.*
The video said that "each point represents an entire galaxy of stars." What does this mean, and how can this help us understand the Hubble Deep Field photo?	*We are so far away that the stars in the galaxy look like one point of light. The splotches in the Hubble Deep Field are probably galaxies full of stars.*

Assessment Opportunity

Building towards: 16.B Obtain and synthesize information across multiple sources about the organization of space systems in our universe from the human scale to the galactic scale.

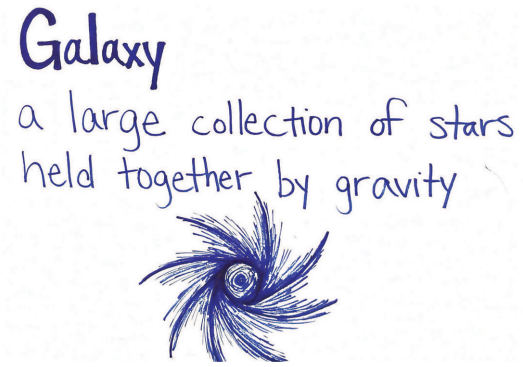
What look/listen for: Use this discussion as an opportunity to formatively assess students's ideas and respond in the moment to push student thinking.

What to do: This is the first time in this unit students have used this element. To support them, use probing questions to clarify student ideas and encourage students to use gestures and drawings to express themselves. Here are some examples:

- I heard you say that gravity makes things go down, is that accurate?
- What do you mean when you say the galaxy is a circle? Can you show me with your hands or sketch a picture on the board?
- I heard you say that the stars are very far away. How does that affect what we see when we look at a galaxy?

Agree on a definition for *galaxy.* Say, *We decided that each of the objects in the Hubble Deep Field photo were galaxies. How should we define the word* galaxy? Accept all student ideas. Highlight ideas about galaxies having a lot of stars and about gravity. If gravity does not come up naturally, ask students what they think keeps all the stars together instead of flying into space.

Summarize by saying, *A galaxy is a large collection of stars held together by gravity, just like how the planets orbit around our Sun, defining the boundaries of our solar system, all the stars in the Milky Way galaxy orbit around its center, defining the boundaries of the galaxy.*

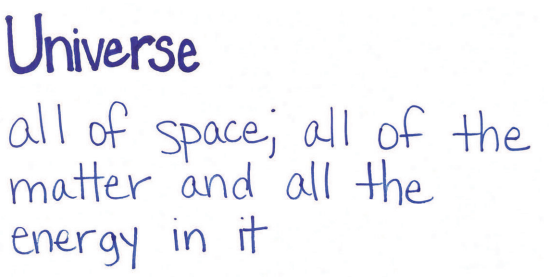


Agree on a definition for *universe.* Then say, *I have also heard a couple of people use the word* universe *over the past few weeks. What do we mean when we say* universe? Look for students to say that "universe" describes everything we know about in space. Some students might mention the possibility of other universes.

Summarize by saying, *The universe is all of space, all of the matter, and all the energy in it. This includes the parts we can see and the parts we can't.*

Take the time to add these words *(galaxy* and *universe*) to the Word Wall.

Connect back to the Shapley-Curtis debate. Present slide G and direct students' attention back to *The Great Debate.*



Suggested prompts	Sample student responses
Who had the correct model, Shapley or Curtis?	*Curtis! There are many galaxies.*
Was Curtis totally right? Or was there something Shapley had right in his model?	*We are not in the center of the Milky Way, we are on the edge, like in Shapley's model.*
Both Shapley and Curtis included gravity in their models. Why is gravity important for explaining the structure of the universe?	*Because it keeps the systems together and determines how everything moves in orbits.*
How does gravity keep systems together? I thought gravity was a force between two objects. What are the objects that are interacting through gravity?	*the Moon and Earth* *Earth and the Sun* *the Sun and the Milky Way galaxy* *the Milky Way and a cluster of galaxies*

Make a public record of these ideas. Write down students' ideas about objects that are interacting through gravity on chart paper titled "Objects that Interact through Gravity".

Key Ideas

Purpose of the discussion: To establish the important parts and interactions in a dynamic model of the universe that matches recent data.

Listen for these ideas:

- Earth orbits the Sun, making the Sun and Earth part of our solar system, along with other planets, asteroids, comets, and so forth.
- Moons orbit planets, creating subsystems of the solar system.
- The entire solar system orbits the center of the Milky Way, which is a galaxy.
- Gravity appears to determine this organization because orbits are caused by interactions between two objects due to gravity force pairs.

5. Navigation

5 MIN

Materials: None

Connect these ideas back to our questions about where we are in all of this. Display **slide H.** Ensure students have access to the DQB questions. Say, *which of our questions did you feel we answered today? How does what we figured out connect to our lives on Earth?*

Look for students to mention questions about galaxies, the universe, anything beyond the solar systems, etc. Propose coming back down to help ground ourselves in this massive system and return to our connections. Say, *We have figured out so much about how systems all over the universe are connected and work. Can we return to Earth next time to try and put this all together and revisit how these patterns are connected to our lives.*

LESSON 17

How are we connected to all of the systems in space beyond the planet we live on?

Previous Lesson *We looked at a photo taken by the Hubble telescope of the space between stars and saw galaxies. We watched the Tour of the Universe to visualize how scientists model the universe at various scales. We noticed that the universe appears to be organized into systems held together by gravity, separated by vast emptiness.*

This Lesson

Putting Pieces Together

2 DAYS



NASA/JPL-Caltech

We make a classroom consensus model at various scales to show how gravity organizes the universe. We return to the DQB to take stock of how far we have come in this unit and then reflect on the unit and Earth's place in the universe.

Next Lesson *There is no next lesson.*

Building Toward NGSS

MS-ESS1-1, MS-ESS1-2, MS-ESS1-3, MS-PS2-4, MS-PS4-2

What Students Will Do

17.A Develop a model of the universe that shows how gravity forces cause the patterns of motion and organization of objects in space systems at multiple scales.

What Students Will Figure Out

- We can explain why there is a similar pattern in the motion structure and organization of the largest scale objects and systems in the known universe, using the same interactions (gravitational forces that are acting on those objects).
- We can answer many of our Driving Question Board questions!

Lesson 17 • Learning Plan Snapshot

Part	Duration	Summary	Slide	Materials
1	10 min	**NAVIGATION** Share connections to patterns and phenomena in the sky.	A-B	Patterns and Phenomena in the Sky poster
2	15 min	**DEVELOP A SMALL GROUP MODEL OF THE UNIVERSE** Organize all the different systems and subsystems so we can figure out how we are connected here on Earth to all of these patterns.	C-D	*Tour of the Universe,* chart paper, markers, Objects that Interact through Gravity poster (from Lesson 16)
3	10 min	**CONDUCT A GALLERY WALK** Hold a brief gallery walk and then develop a classroom consensus model in a Scientists Circle.	E	optional online interaction (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper titled "Classroom Consensus Model for the Universe", markers
4	10 min	**REVISE SMALL GROUP MODELS** Groups return to and revise their models.	F	
				End of day 1
5	15 min	**DEVELOP A FINAL CONSENSUS MODEL** Develop a classroom consensus model in a Scientists Circle.	G	optional online interaction (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper titled "Classroom Consensus Model for the Universe", markers
6	10 min	**EVALUATE OUR DQB QUESTIONS** In pairs, students evaluate our list of DQB questions and indicate the progress they think we have made on each. Then students place sticky dots on the questions they think we have made progress on.	H-I	*Reviewing Our Driving Question Board,* sticky dots
7	10 min	**REVISIT THE DRIVING QUESTION BOARD (DQB)** Revisit the DQB with the whole class and take stock of all the questions we've now answered.	J	*Hubble eXtreme Deep Field,* sticky dots
8	10 min	**REFLECT ON THE PALE BLUE DOT** Read about the Pale Blue Dot image and reflect on our place in the universe.	K	*The Pale Blue Dot,* 8.4 Lesson 17 Reflections on the Pale Blue Dot (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)
				End of day 2

Lesson 17 • Materials List

	per student	per group	per class
Lesson materials **Student Procedure Guide**  **Student Work Pages** 	• science notebook • *Tour of the Universe* • *Reviewing Our Driving Question Board* • sticky dots • *Hubble eXtreme Deep Field* • *The Pale Blue Dot*	• chart paper • markers	• Patterns and Phenomena in the Sky poster • Objects that Interact through Gravity poster (from Lesson 16) • chart paper titled "Classroom Consensus Model for the Universe" • markers • 8.4 Lesson 17 Reflections on the Pale Blue Dot (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Materials preparation (20 minutes)

Online Resources



Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Take a high-resolution photograph of all the questions on the DQB or type them into *Reviewing Our Driving Question Board*.

Make sure the DQB is displayed and space is available for the class to gather in a Scientists Circle.

Display around the room all previous classroom consensus models for the unit.

Test Reflections on the Pale Blue Dot video at 8.4 Lesson 17 Reflections on the Pale Blue Dot (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**).

Lesson 17 • Where We Are Going and NOT Going

This is the final lesson of the unit. This lesson provides a final opportunity for students to explain how they will develop a consensus model for the universe with the purpose of describing how we are connected to patterns we can and cannot see in the sky.

LEARNING PLAN FOR LESSON 17

1. Navigation

10 MIN

Materials: science notebook, Patterns and Phenomena in the Sky poster

Navigate. Present **slide A.** Say, *We started our unit by looking at an interesting repeating pattern in the sky and hearing the stories of other people's connections to the sky. Let's begin today by reconnecting to those phenomena and patterns we felt were important in our lives or of those in our community.* Have students make a chart in their science notebook with the following headings:

- Patterns and phenomena in the sky that matter to me
- What we figured out in the unit about those patterns and my connections

Walk over and point to the Patterns and Phenomena in the Sky poster that has been referenced throughout the unit. Students can use this as a jumping off point for their connections. Give students 3 minutes to work on their own. Present slide B and have students turn and talk with a partner about what they recorded in their science notebook. After a few minutes, ask for a few volunteers to share their discussions with the class. As students share, listen for connections to the Sun, Moon, stars, color and appearance changes, and any mechanisms behind movement in the sky. Then say, *I loved hearing all of your connections. Do you think we can try and put all of those ideas together in one large system that explains how everything is connected together?*

2. Develop a small group model of the universe.

15 MIN

Materials: *Tour of the Universe,* chart paper, markers, Objects that Interact through Gravity poster (from Lesson 16)

Motivate the modeling. Present **slide C**. Read the prompt on the slide: *We now know that other stars have rich systems as well, with planets and probably moons and other objects, but that there is a lot of empty space in between all these parts and systems. Why is it that we find things in space clumped together, with so much emptiness in between, instead of spread out evenly? Can we make a model of the universe that shows and explains this structure?*



Create final models of the universe. Present **slide D.** Remind students that they have for reference *Tour of the Universe* from 8.4 Lesson 16 Tour of the Universe (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) and the Objects that Interact through Gravity poster.*****

Break students into groups of 3–4 and have each group develop a model at multiple scales for the universe and draw their representation on chart paper to create their poster. Move around the room to make sure that students are using zooming to model multiple scales, including a scale where we can see multiple galaxies. Ask students to hang their posters along the walls when they are finished.

*** Supporting Students in Developing and Using Scale, Proportion, and Quantity**
To support students in zooming in or out of the solar system, smaller systems, or galaxies, remind students of the work they did in the *Unit 6.6: How do living things heal? (Healing Unit)* to model the systems and subsystems in the body involved in healing the foot injury.

Assessment Opportunity

Building towards: 17.A.1 Develop a model of the universe that shows how gravity forces cause the patterns of motion and organization of objects in space systems at multiple scales.

What to look/listen for: Look for students to include multiple scales and to be able to articulate the reasons why their model looks like that:

- Students could say, "The space between each scale is enormous and empty, so we model only the interesting bits/objects/interactions that account for patterns we observe that we want to be able to explain."
- Include at least 2 (possibly 3 or more) scales of systems:
  - Many galaxies (clusters and/or groups and/or islands and/or spirals of many stars) with empty space between each galaxy
  - Our solar system (including our planet Earth and some other planets with empty space between them, nested within a small part of a larger system that is one single galaxy, the Milky Way Galaxy)
  - Additional subsystems within the solar system may be represented that includes moons and planets (e.g., Earth and its Moon and/or other planets and their moons), though this subsystem may also end up being represented/subsumed into the larger solar system model
- Gravity dictates this organization. Students may represent gravity forces on their models. If they don't, use probing questions to get them thinking about gravity in their models. Any one of these lines of thinking would be appropropriate to look for, though it is unlikely that students would represent all of these:
  - Gravity forces act on all objects in space.
  - Gravity pulls nearby smaller objects (or pieces of matter) in each system together and/or toward other larger objects.
  - Optional: this is why a lot of empty space exists between objects in every system.
  - The speed of many of those objects and the gravity pulling on them keeps them moving in repeating paths of motion around objects (orbits that are circular or elliptical paths of motion).
  - Challenging and optional: The path of motion and/or direction that an object is moving while in orbit at any point in time is different than the direction of the (net) gravity force(s) of acting on it.

What to do: Use probing questions to focus student attention on the interactions that each scale has in common.

- *It seems like we have different parts/objects in focus at different scales, but are the interactions between those objects different or are they the same?*
- *Why do all the parts of the solar system stay in the solar system? Why don't they fly out into the galaxy, filling up the space between star systems?*
- *Why don't the stars, which we also know are moving, stay in the galaxy? Why don't they fly out, filling up the space between the galaxies? Is this different from the reason why Earth and other planets don't fly away from our Sun or is it the same? How about why the Moon doesn't fly away from Earth?*

3. Conduct a gallery walk. 10 MIN

Materials: science notebook, optional: Galaxy Zoo website (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper titled "Classroom Consensus Model for the Universe", markers

Hold a brief gallery walk. Present **slide E.** Send groups on a gallery walk to visit at least 3–4 other posters and notice similarities and differences across models related to

- how each model uses "zooming" to represent multiple scales,
- which important parts of the systems each model includes, and
- how each model shows how these systems are held together through interactions among the parts.

You can rotate groups through all posters if there is time or choose models to visit that have few or no students at them already.

Alternate Activity

If there is not enough time for a gallery walk, you can have students hang their posters and then move on to the Consensus Discussion, referencing the posters during the Scientists Circle. If you choose to do this, make sure to probe students as they make suggestions for the consensus model. Example questions follow:

- *Do you see any examples of that on the posters around the room?*
- *When you look around at the posters, does it look how most people represented that?*

4. Revise small group models. 10 MIN

Materials: None

Return to small groups and revise models. Display **slide F.** After visiting other small-group models, students should return to their group model and add any additional information they think will clarify their thinking before heading into developing a classroom consensus model together.

End of day 1

5. Develop a final consensus model. 15 MIN

Materials: science notebook, optional: Galaxy Zoo website (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**), chart paper titled "Classroom Consensus Model for the Universe", markers

Gather in a Scientists Circle to develop a classroom consensus model. Present **slide G.** In a Scientists Circle, draw students' attention to a piece of chart paper titled "Classroom Consensus Model for the Universe." As students are walking over, have them think about the prompts on slide G to prepare for the whole class discussion.

Ask, *What objects did you notice at different scales on the posters that you think we should include in our model?* Look for students to suggest the following:

- galaxies (or clusters of galaxies) are the largest objects
- stars or star systems (or inside the Milky Way or the Milky Way)
- our solar system
- the Earth-Moon system (optional)



Establish the role of gravity in the model.

Suggested prompts	Sample student responses
Why is it that we find objects at these different scales in space clumped together with so much emptiness in between instead of spread out evenly?	*Stuff is orbiting something.* *Gravity is holding each system together.* *Gravity forces are stronger when objects are close together, so exoplanets orbiting other stars will be pulled toward those stars, not toward our Sun. Stars are really far apart, so they are not interacting with each other.*
Why do the stars in the Milky Way orbit around the center of the galaxy if they are very far away from it?	*Maybe it's really massive?* *(Accept all responses.)*
Is distance the only thing that makes gravity forces stronger? Look back in your notebook at Lesson 5.	*Gravity is also dependent on mass.*
What does this tell us about whatever is at the center of the Milky Way galaxy?	*Something very massive must be at the center of the galaxy. (Students might not get here, but if they do, there is an optional home learning about supermassive black holes discussed below.)*

Alternate Activity

Extension Opportunity: For an extension opportunity, if your students are interested in black holes, assign the National Geographic article on black holes as home learning. Ask students to consider as they read our question about what could be at the center of the Milky Way that is creating such strong gravitational force pairs to keep stars in orbit. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Assessment Opportunity

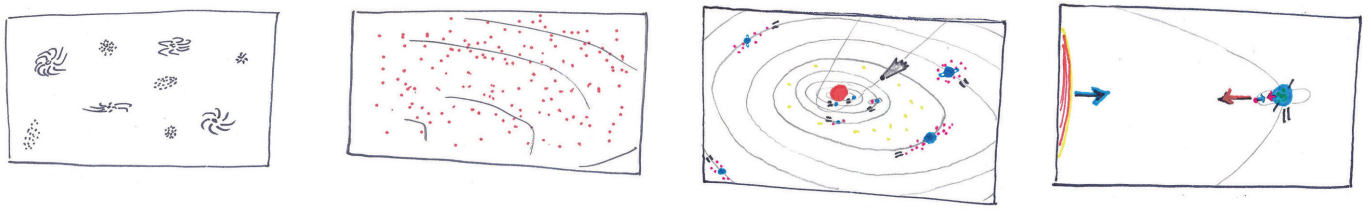
Building towards: 17.A.2 Develop a model of the universe that shows how gravity forces cause the patterns of motion and organization of objects in space systems at multiple scales.

What to look/listen for: Look for students to articulate the role of gravity in bounding space systems by keeping things in orbit around more massive things.

What to do: If students included gravitational interactions in their models, this may come naturally. If not, use probing questions to focus student attention on the interactions that each scale has in common. Such as the following:

- *It seems like we have different parts/objects in focus at different scales, but are the interactions between those objects fundamentally different, or are they due/produced/caused by the same things?*
- *Why do all the parts of the solar system stay in the solar system? Why don't they fly out into the galaxy, filling up the space between star systems?*
- *Why don't the stars, which we also know are moving, stay in the galaxy? Why don't they fly out, filling up the space between the galaxies? Is this different than the reason for why Earth and other planets don't fly away from our Sun or is it the same? How about why the Moon doesn't fly away from Earth?*

Model each scale as a class, zooming backward toward Earth.



Say, *Let's start with the largest scale and zoom in. What did you notice on most or all of the posters that we should include at the largest scale?* Look for students to suggest galaxies. Note that students are not expected to know anything about the structure of galaxies, so accept however they choose to represent galaxies as a class, whether as spirals, circles, large clusters of stars, or some combination of shapes. Ask, *Where did you see gravity forces modeled in this system?*

Ask, *What should we zoom in on here to model next?* Look for students to suggest zooming in on one of the galaxies. Students may suggest zooming in on a couple of star systems or zooming in on a larger swath of the Milky Way. Either is fine. Draw a box around where students want to zoom and then a line pointing to a new diagram. In the new diagram, draw another model with the parts and interactions students agree on. Ask, *Where did you see gravity forces modeled in this system?*



Repeat this until students have zoomed in on our solar system. At this scale, look for students to suggest planets and the Sun. They may also suggest moons, asteroids, and/or comets. Do your best to include all the solar system objects that students suggest, but do not fish for more beyond planets and the Sun. Ask, *Where did you see gravity forces modeled in this system?*

Students may or may not decide to zoom in further to show some of the details of the Earth-Moon system or how gravity force pairs cause orbits in more detail. Record in a key the conventions you decide on as a class.

6. Evaluate our DQB questions.

10 MIN

Materials: science notebook, *Reviewing Our Driving Question Board,* sticky dots

Have students work in pairs to evaluate what questions the class has answered from the DQB.* Display **slide H.** Provide students with *Reviewing Our Driving Question Board,* which you created to contain all the student questions from the DQB, and have students tape it into their science notebooks. Have students work with a partner to mark questions they think the class has answered:

- We did not answer this question or any parts of it yet: O
- Our class answered some parts of this question, or I think I could answer some parts of this question: ✓
- Our class answered this question, or using the ideas we have developed, I could now answer this question: ✓+

*** Attending to Equity**
Revisiting the DQB is an important process in allowing students to feel their thoughts and questions are valued and recognized. This part of the lesson helps students see the hard work they have done to answer many of their own questions.

Additional Guidance

Revisiting the DQB is important for students to feel as though their questions are valued and recognized. While not questions will have been addressed (it's more likely that 50–75 percent will be at least partially answered), this helps students see that they have done this hard work to answer many of their own questions.

Review and share the questions that students think we have answered. Present **slide I** and have students mark the class DQB with sticky dots on the questions that they think we have made progress on. Give each pair 10 sticky dots.

7. Revisit the Driving Question Board (DQB).

10 MIN

Materials: science notebook, *Hubble eXtreme Deep Field*, sticky dots

Look for patterns using the sticky dots. Move into the Scientists Circle and focus on the questions that have the most number of sticky dots. Discuss as a class the questions that students can now answer.* Present **slide J** if needed. Have the class discuss the answers to those questions as a group. If you have space, you might make a Takeaways board that has a record of the answers the class comes up with. Have extra sticky dots available in case students realize there are answered questions that are missing a dot.

*** Supporting Students in Engaging in Asking Questions and Defining Problems**
Revisiting the DQB at the end of the unit helps students see the progress they have made toward answering questions that were important to them. Students were tasked with asking questions "that required sufficient and appropriate evidence to answer." Through the investigations in the unit and individual and whole-group sensemaking, they can now answer many of the questions.

8. Reflect on the pale blue dot.

10 MIN

Materials: *The Pale Blue Dot*, 8.4 Lesson 17 Reflections on the Pale Blue Dot (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**)

Present **slide K** and pass out *The Pale Blue Dot*. Ask students to use the handout to reflect on the unit and Earth's unique place in the universe. Play 8.4 Lesson 17 Reflections on the Pale Blue Dot for the class. (See the **Online Resources Guide** for a link to this item. **www.coreknowledge.org/cksci-online-resources**) If there is time, ask students to share their reflections with a partner or with the whole class. You might also consider posting these reflections around the room for a gallery walk or having students pass them around so that others can read them.



The pale blue dot. NASA/JPL-Caltech

Teacher Resources

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Assessment System Overview

Each unit includes an assessment system that offers many opportunities for different types of assessments throughout the lessons, including pre-assessment, formative assessment, summative assessment, and student self assessment. Formative assessments are embedded and called out directly in the lesson plans. Please look for the "Assessment Icon" in the teacher support boxes to identify places for assessments. In addition, the table below outlines where each type of assessment can be found in the unit.

Overall Unit Assessment

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 1	*My Initial Model to Explain: _____, Initial Manhattanhenge Model* Patterns and Phenomena in the Sky Poster Driving Question Board	**Pre-Assessment** The student work in Lesson 1 available for assessment should be considered a pre-assessment. It is an opportunity to learn more about the ideas your students bring to this unit. Revealing these ideas early on can help you be more strategic in how to build from and leverage student ideas across the unit. The Initial Manhattanhenge Model on day 1 of Lesson 1 allows you to pre-assess what students are bringing in from earlier grade bands and units, across all three dimensions. The initial model to explain a chosen pattern in the sky developed on day 3 of Lesson 1 is a good opportunity to pre-assess student understanding of which parts of the system are important to explaining patterns and phenomena in the sky, what students already know about space, and areas of engagement to draw up later in the lesson/unit. Throughout the lesson, students will add ideas to the Patterns and Phenomena in the Sky Poster. Listen for students to not only make DCI level connections to patterns with the objects in the solar system, stars, and galaxy but also to their personal life to leverage their engagement throughout the unit. The Driving Question Board is another opportunity for pre-assessment. Reinforce for students to generate open-ended questions, such as how and why questions and to post to the board. However, any questions students share, even if they are close-ended questions, can be valuable. Make note of any close-ended questions and use navigation time throughout the unit to have your students practice turning these questions into open-ended questions when they relate to the investigations underway.
Lesson 4	*What causes the seasons in Australia and why are they opposite of our seasons?* *What causes the seasons in Australia and why are they opposite of our seasons?*	**Summative** There is a summative assessment early in this unit because there are several key ideas around seasonal temperature variation that we will not revisit in the unit. This assessment asks students to use their Gotta-Have-It Checklists, seasonal temperature variation data in the assessment, and a model to explain what causes the varied temperatures (effect in different seasons in Australia like we heard about in the podcasts). The assessment also asks students to explain seasons and temperature variation by comparing the Northern and Southern Hemispheres.

When	Assessment and Scoring Guidance	Purpose of Assessment
Lesson 7 and 8	Physical Models, Predictive Model, *Lesson 7: Self-Assessment for Collaborative Group Work*, Predictions L7 and L8 Assessment Scoring Guidance	**Formative and Self-Assessment** In this assessment opportunity, students work in groups to develop a Earth-Sun-Moon system model to explain when and why we can see a solar eclipse. During the modeling, students should use their physical models to communicate about the relationship of where an observer is on Earth and the Moon's position relative to the Sun and Earth so that the observer would see a solar eclipse. Students will also have an opportunity to reflect on their use of different models to compare the purpose of each model and identify the boundaries and limitations of each. Students identify the purpose of using both physical and drawn models—including different perspectives—and their various limitations. If time permits, students can complete *Lesson 7: Self-Assessment for Collaborative Group Work* as part of their reflection. At the beginning of Lesson 8, students use the classroom consensus model to develop an individual prediction for lunar eclipses in their notebooks which they return to reflect on what they model did and did not correctly predict on *Analyzing Lunar Eclipse Images*.
Lesson 12	*Explaining Fishing Related-Phenomena* *Explaining Fishing-Related Phenomena*	**Summative** In this assessment, students have an opportunity to demonstrate their understanding of how light travels through different mediums to explain why a certain color of a fishing lure would be a better choice for fishing than other colors that are less visible underwater at the depths where fish live. Students apply science ideas to explain why some colors are more visible than others underwater and how an object can appear in a different location than they actually are underwater. Students use their ideas about how light travels through the atmosphere to compare to what is visible underwater.
Lesson 17	Small Group Model Assessment (on chart paper)	**Summative** In this assessment, students work in small groups to develop a model to demonstrate their understanding about the role gravity forces play in the organization of objects of various scales (galaxies, solar systems, planet-moon systems) in the universe. During a gallery walk, students notice similarities and differences between their small group model and other small group models and use those to revise their original group's model. Finally, students work to develop a class consensus model of the universe. Students apply ideas about factors that influence gravity forces to shape the universe and develop explanations for why so much of the universe is composed of empty space. They build a model of the universe showing nested subsystems of galaxies, solar systems within galaxies, and planet-moon systems within solar systems.
After each lesson	Lesson Performance Expectation Assessment Guidance	**Formative** Use this document to see which parts of lessons or student activity sheets can be used as embedded formative assessments.

When	Assessment and Scoring Guidance	Purpose of Assessment
Occurs in several lessons	Progress Tracker	**Formative and Self-Assessment** The Progress Tracker is a thinking tool that was designed to help students keep track of important discoveries that the class makes while investigating phenomena and figure out how to prioritize and use those discoveries to develop a model to explain phenomena. It is important that what the students write in the Progress Tracker reflects their own thinking at that particular moment in time. In this way, the Progress Tracker can be used to formatively assess individual student progress or for students to assess their own understanding throughout the unit. Because the Progress Tracker is meant to be a thinking tool for kids, we strongly suggest it is not collected for a summative "grade" other than for completion.
Anytime after a discussion	Student Self Assessment Discussion Rubric	**Student Self-Assessment** The student self-assessment discussion rubric can be used anytime after a discussion to help students reflect on their participation in the class that day. Choose to use this at least once a week or once every other week. Initially, you might give students ideas for what they can try to improve for the next time, such as sentence starters for discussions. As students gain practice and proficiency with discussions, ask for their ideas about how the classroom and small group discussions can be more productive.
After Students Complete Substantial Meaningful Work	Peer Feedback Facilitation: A Guide	**Peer Feedback** There will be times in your classroom when facilitating students to give each other feedback will be very valuable for their threedimensional learning and for learning to give and receive feedback from others. We suggest that peer review happen at least two times per unit. This document is designed to give you options for how to support this in your classroom. It also includes studentfacing materials to support giving and receiving feedback along with self-assessment rubrics where students can reflect on their experience with the process. Peer feedback is most useful when there are complex and diverse ideas visible in student work and not all work is the same. Student models or explanations are good times to use a peer feedback protocol. They do not need to be final pieces of student work, rather, peer feedback will be more valuable to students if they have time to revise after receiving peer feedback. It should be a formative, not summative type of assessment. It is also necessary for students to have experience with past investigations, observations, and activities where they can use these experiences as evidence for their feedback. For this unit, Peer Feedback works best for Lessons 8, 10, 13, and 14 during the consensus moments where students are sharing their consensus models, or after an investigation where students share what they figured out with peers.

For more information about the approach to assessment and general program rubrics, visit the Teacher Handbook.

Lesson-by-Lesson Assessment Opportunities

Every lesson includes one or more lesson-level performance expectations (LLPEs). The structure of every LLPE is designed to be a three-dimensional learning, combining elements of science and engineering practices, disciplinary core ideas and cross cutting concepts. The font used in the LLPE indicates the source/alignment of each piece of the text used in the statement as it relates to the NGSS dimensions: alignment to Science and Engineering Practice(s), alignment to Cross-Cutting Concept(s), and alignment to the Disciplinary Core Ideas.

The table below summarizes opportunities in each lesson for assessing every lesson-level performance expectation (LLPE). Examples of these opportunities include student handouts, home learning assignments, progress trackers, or student discussions. Most LLPEs are recommended as potential formative assessments. Assessing every LLPE listed can be logistically difficult. Strategically picking which LLPEs to assess and how to provide timely and informative feedback to students on their progress toward meeting these is left to the teacher's discretion.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 1	**1.A** Ask questions about systems in space that arise from observations of patterns in the sky. **1.B** Obtain information from images, videos, and podcasts to describe patterns in natural phenomena of objects in the Solar System (and beyond), as seen from Earth. **1.C** Develop an initial model of systems in space to describe patterns we observe in the sky.	**1.A Asking Questions; Patterns** **When to check for understanding:** • **Day 1 -** Notice the kinds of patterns students come up with as they begin to build the "Patterns and Phenomena in the Sky Poster" on Day 1. • **Day 4 -** Take note as the class builds the DQB on Day 4. **What to look/listen for:** • **Day 1 -** Use this as a pre-assessment to gauge how much your students already know about space. Listen for students to list observable phenomena connected to not only the motion of objects in the sky/space but also their appearance. Objects may include the Sun, Moon, stars, and planets. Some students may be suggesting comets and galaxies, while other students might suggest that the Sun goes around the Earth. • **Day 4 -** As the class builds the Driving Question Board, listen for: (1) the subsystems, patterns, and changes in objects that students are asking questions about; and (2) how the questions relate to patterns and systems. Possible systems/subsystems could include the Earth–Sun, Earth–Moon, Earth–Sun–Moon, other objects in the Solar System, color changes of objects such as planets/moons/suns/stars/galaxies, shape changes (or eclipses/transits) or visibility changes for these different objects. **1.B Obtaining Information; Patterns; Systems and System Models** **When to check for understanding:** On Day 2, as students are listening to the podcast and filling out *Making Sense of the Podcast Jigsaw*, and during the Building Understandings Discussion about what they noticed, wondered, and connected to in the podcasts.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
		What to look/listen for: Students should use the strategies and prompts on *Listening Group Roles Reference* to obtain and document information from the podcasts on *Making Sense of the Podcast Jigsaw* about the patterns and phenomena described by each interviewee and the connections to the sky. Listen for students to refer to the phenomena from each podcast. Podcast-specific guidance is described further in the related assessment callout box. **1.C Developing and Using Models; Systems and Systems Models; Patterns** **When to check for understanding:** On Day 3, circulate the classroom during the gallery walk to observe students' models. **What to look/listen for:** Look for students who are including parts or interactions in their system that might not be necessary to explain the pattern they chose as opposed to the necessary parts and interaction. For example, a student might have chosen to model seasons but included all eight classical planets in orbit around the Sun in their model. In addition, look for students who are representing scale in their models by indicating "zooming" of perspectives. This is a sophisticated way to represent scale and will become part of our consensus models later in the unit. Make note of these models to highlight in Lesson Set 4.
Lesson 2	**2.A** Use a graphical display (a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in location of sunrise/moonrise and sunset/moonset, the paths of motion of the sun and moon, and and how most stars move and which one doesn't in the sky at night) in a large data set (across 6 months from a specific location on earth's surface).	**2.A Developing and Using Models; Analyzing and Interpret Data; Patterns** **When to check for understanding:** Student initial models should incorporate temporal and spatial data from the website to help explain the patterns of movement of objects in the sky. **What to look/listen for:** Models should identify that temporal and spatial patterns of movement of objects in the sky are due to Earth's spin on its axis. One object, the North Star, does not appear to move in the sky because Earth's axis is pointed toward it.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 3	**3.A** Use a graphical display (simulated motion from a virtual fisheye projection of the sun, moon, and stars in the sky and compass points across the horizon) to identify temporal and spatial relationships (patterns in solar elevation and length of day) in a large data set (across 6 months from a specific location on earth's surfaces). **3.B** Collect and produce data showing patterns of changes in daylight and the angle of elevation of the Sun in the sky to serve as evidence to evaluate the accuracy of an initial physical Earth–Sun System model. **3.C** Revise a model of the patterns of movement of the Earth around the Sun to explain that changes in the amount of sunlight and angle of elevation of the Sun in the sky during the year is due to Earth's axis being tilted toward Polaris.	**3.A Analyzing and Interpreting Data; Patterns** **When to check for understanding:** As students make observations and record data from the Measuring the Sun videos on day 1. **What to look/listen for:** Students should record that the angle of the Sun in the sky and hours of daylight increases from January to June and decreases from June to December. **3.B Planning and Carrying Out Investigations; Patterns** **When to check for understanding:** As students use data to evaluate the accuracy of their models, after the class makes measurements using a physical model of the Earth–Sun system, and during the navigation on day 2. **What to look/listen for:** Students should identify that the data they collected from the NOAA websites do not match up with the data the class measured using the physical representation of our models. **3.C Developing and Using Models; Patterns** **When to check for understanding:** On day 3, collect student notebooks to evaluate their Progress Tracker models. **What to look/listen for:** Students should identify that the patterns of changes in the amount of sunlight and angle of elevation of the Sun in the sky are caused by Earth's tilt and location as it orbits around the Sun.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 4	**4.A** Develop, revise, and use models of the Earth-Sun system to create mathematical relationships of the seasonal patterns of the position of the Sun in the sky and of temperatures over the surface of Earth. **4.B** Develop and use models of the Earth-Sun system to explain the cause-andeffect relationships between Earth's tilt, solar elevation, and sunlight energy on Earth's surface to explain seasonal temperature differences.	**4.A. Developing and Using Models; Patterns** **When to check for understanding:** Day 1: During the Building Understanding Discussion. Day 2: During the Gotta-Have-It Checklist, listen to the way that students are describing how the tilt of Earth affects seasonal temperature. **What to look/listen for:** That the tilt of the Earth affects the concentration of the energy reaching the surface and the length of time that energy reaches the surface (daylight hours) over the year, and both of these together contribute to seasonal changes in temperatures. **4.B Developing and Using Models; Cause and Effect** **When to check for understanding:** On day 2 when students are completing *What causes the seasons in Australia and why are they opposite of our seasons?*. **What to look/listen for:** See *What causes the seasons in Australia and why are they opposite of our seasons?* for guidance.
Lesson 5	**5.A** Develop and use a model of the Earth-Sun system to explain how Earth's fixed tilt and orbit would cause a cyclical pattern in the location of the Sun at sunset that repeats every year.	**5.A Developing and Using Models; Patterns** **When to check for understanding:** Listen to what students share as they complete *Connecting Patterns in the Sun to Manhattanhenge* and during the consensus model and read what they write in the following Stop and Jot. **What to look/listen for:** Student explanations of the model and noticings while watching the video should include ideas about how the tilt of Earth's axis causes the location (direction on the horizon) of sunrise and sunset to change during the year. The path of the Sun and angle of the Sun in the sky (solar elevation) changes during the year. When a hemisphere is tilted toward the Sun, the solar elevation is higher in the sky and results in a longer path across the sky. Manhattanhenge occurs in May and June because this longer path results in the Sun being at a point on the horizon where the sunlight from it travels in a straight line between the building to observers along the street.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 6	**6.A** Develop and use a model of the Earth-Sun-Moon system to explain and predict patterns we observe in the way the apparent shape of the Moon changes over time.	**6.A Developing and Using Models; Patterns** **When to check for understanding:** • On day 1, collect the second copy of *Lesson 6: My Initial Model to Explain:* _____. • On day 2, when students are independently recording their ideas on *Shape Patterns of Earth-Sun-Moon System*. **What to look/listen for:** • On the second copy of *Lesson 6: My Initial Model to Explain:* _____, students should be able to predict with their models what phase of the Moon follows the current one (accept either the phase before or after the current one since at this point students haven't figured out the direction of the Moon's orbit around Earth). • On *Shape Patterns of Earth-Sun-Moon System*, students should be able to sketch how the position of the Moon and its interaction with the Sun affect what we see of the Moon in its various phases.
Lesson 7	**7.A** Develop and use a model of the Earth-Sun-Moon system to explain why and when we can see a solar eclipse.	**7.A Developing and Using Models; Systems and System Models** **When to check for understanding:** • Day 1: When groups use physical models to explain the interactions of the Earth-Moon-Sun system that causes a solar eclipse • Day 2: During the whole-class discussion about limitations of our models **What to look/listen for:** • Day 1: Students should use their physical models to communicate about the relationship of where an observer is on Earth and the Moon's position relative to the Sun and Earth so that the observer would see a solar eclipse. • Day 2: Students reflect on their use of different models to compare the purpose of each model and identify the boundaries and limitations of each. Students identify the purpose of using both physical and drawn models—including different perspectives—and their various limitations.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 8	**8.A** Evaluate the limitations of our system model predicting what we would see during a lunar eclipse.	**Developing and Using Models; Systems and Systems Models** **When to check for understanding:** When partners are discussing their analysis of the lunar eclipse images. **What to look for/listen for:** Listen for students to mention ideas such as the following: • Our model predicted that the Moon would get darker. It did get dimmer, but not exactly how we thought. • Our model predicted that the darkness or shadow would move from one side of the Moon to the other; it did. • Our model predicted that the eclipse would only happen during a full Moon; it did. • Our model predicted that the Moon would not be visible when it was totally in the Earth's shadow, but it was visible (just dimmer and reddish!). • Our model did not predict that the Moon would turn reddish.
Lesson 9	**9.A** Revise our Earth–Sun system model to include ideas about how the Earth's atmosphere causes light from the Sun and Moon to change colors.	**9.A Developing and Using Models; Cause and Effect** **When to check for understanding:** When partners are using the revised model to suggest possible causes for color change we see in the Sun at sunrise/sunset **What to look/listen for**: As students talk with their partners and then again during the upcoming discussion, listen for students to share ideas such as these: • Person A (seeing sunrise) is seeing a dimmer, reddish-orange-colored Sun because the light that reaches their eyes has passed through more of the atmosphere. • Person B (midday) is seeing a brighter yellower/whitish Sun because the light reaching their eyes has passed through less of the atmosphere. • Materials in the atmosphere (such as water vapor, clouds of water droplets and ice, other gasses, dust, and pollution) are affecting the color of light from the Sun—the more atmosphere the light travels through (such as for Person A), the more effect (more color change) we see. • Other differences in the atmosphere (more pollution in some places than others, for instance) could also affect the color or intensity of light that people see from the Sun at their position.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 10	**10.A** Carry out an investigation to collect data as evidence of the effect of light interacting with a simulated atmosphere.	**10.A Planning and Carrying Out Investigations; Cause and Effect** **When to check for understanding:** While students are carrying out the Light and Milky Water Lab, and in their work on *Investigation Elements Map, Predictions, and Results*. **What to look/listen for:** As students carry out the investigation, visit groups and listen for ideas such as these. You can also read their observations and responses to the questions on *Investigation Elements Map, Predictions, and Results* and compare them to the sample responses provided in *Investigation Elements Map, Predictions, and Results*. • The light didn't change color in the clear water from any view. • The light changed color in the milky water: from eye level, it looked yellower, oranger, and redder the more of the atmosphere (longer distance and density of particles) it was traveling through. • The light was dimmer when it was shining through more atmosphere. • Viewed from above, we can see bluish light in the milky water nearer the flashlight, and yellower/oranger/redder light as it moves through the atmosphere. • Based on the results of their investigation of ¼ teaspoon of milk powder, students predict that the simulated atmosphere containing more particles (an additional ¼ teaspoon of milk powder) will cause the light to appear dimmer and redder/oranger. • The light is interacting with the simulated atmosphere: being transmitted and reflected (scattered) differently—that's causing the color changes we see.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 11	**11.A** Conduct an investigation to collect and produce data as evidence to answer scientific questions about relationships of light interacting with differently shaped objects of varying compositions. **11.B** Develop and use a model to describe the separation of white light into different colors (effect) as it travels through different mediums (cause).	**11.A Planning and Carrying Out Investigations; Structure and Function** **When to check for understanding:** Day 1: During the rainbow lab investigation. **What to look/ listen for:** Monitor groups at the stations for observations about the three key ideas: Path of Light, Color Changes, and Brightness of Light. Responses to the reflection questions can be collected or read to check for understanding of patterns. **11.B Developing and Using Models; Cause and Effect** **When to check for understanding:** Day 2: After the group consensus model for path of light when students develop their own model to explain the refraction of light through a triangular prism. **What to look/ listen for:** Students should include that light passing from the light source to the prism is travelling in a straight line. Upon entering the prism, the light angle should change and the respective colors should begin to separate. The light should bend again when leaving the prism and returning to air. Once in the air, the respective spectrum colors should continue in straight lines until reflected off of another surface (like the box in their investigation). Students should note that the light broken into colors is less bright than the white light.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 12	**12.A** Develop and use a model of light in the Earth-Sun-Moon system to describe why the Moon changes color during a lunar eclipse. **12.B** Apply science ideas (selective reflection, absorption and transmission of different colors of light by different media and the refraction of light across different media) and evidence to provide an explanation for what causes the apparent color and location of some objects to change under water (effect).	**12.A Developing and Using Models; Systems and System Models** **When to check for understanding:** On day 1, when small groups work on revising their lunar eclipse model and as you are making the classroom consensus model. **What to look/listen for:** See the key ideas or assessment callout within the lesson. **12.B Constructing Explanations; Cause and Effect** **When to check for understanding:** On day 2, when students are completing *Explaining Fishing Related-Phenomena*. **What to look/listen for:** See scoring guidance on *Explaining Fishing-Related Phenomena*.

Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 13	**13.A** Read an article and use it to determine some observations people have made of one planet (Venus) in the past, the patterns they noticed over time, and different connections that different cultures have made to Venus. **13.B** Construct an explanation of the patterns in the apparent size and shape (scale properties) of Venus from Earth as it orbits the Sun. **13.C** Analyze and interpret data to identify patterns in and between different scale properties for planets and some of their moons in our solar system (including relative size, orbital distance from the Sun, surface features, if any, and atmosphere).	**13.A Obtaining, Evaluating, and Communicating Information; Patterns** **When to check for understanding:** In the specific portions of *Venus in Cultures from Around the World* that students underline and highlight that students make on day 1. **What to look/listen for:** • Identifying Venus as appearing to the 3rd brightest object in the sky, which changes in brightness over time (multiple days). • Identifying Venus as appearing in different portions of the sky (day/night) at different points in time. • Identifying cultural connections, such as associations with a god and/or timing important events, days of the week, or influencing life on Earth. **13.B Constructing Explanations; Patterns, Scale, Proportion, and Quantity** **When to check for understanding:** When students are working on *Explaining Venus-Related Patterns* in small groups at the end of day 2 and in their exit ticket responses they add to the back of this handout. **What to look/listen for:** See *Key: Explaining Venus-Related Patterns* for specific guidance on what to look for in each of the responses for the four different phenomena. For the responses that students write for the exit ticket, look for these additional ideas: • Both Mercury and Venus transits of the Sun have noticeable phases and are never visible at midnight. Both Mars and Jupiter do not match this pattern for any of these. • Mercury's orbit must be similar to Venus in that it orbits the Sun in a path interior to the orbit of the Earth. Optional: Mars and Jupiter, if they orbit the Sun, must follow a path that is not interior to the orbit of the Earth. **13.C Analyzing and Interpreting Data; Patterns; Scale, Proportion, and Quantity** **When to check for understanding:** On day 3, when students are analyzing data from *Looking for Patterns in the Solar System Infographics*. **What to look/listen for:** As students analyze planetary and other solar system object data, look for: • comparing the size of objects in the solar system relative to where they are located, • comparing composition of different planets relative to other planets, • beginning to compare how long it takes the planet to rotate on its axis and how long it takes to go around the main object (the Sun) it orbits, and • begin to notice a relationship between location within the solar system and object size, object speed, and object orbital period.

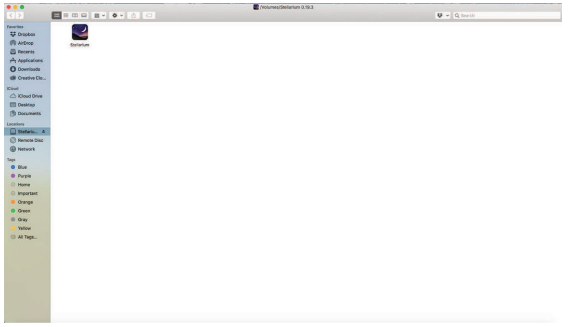
Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 14	**14.A** Develop and revise an initial model of the Earth-Moon system to show the location, strength, and interaction of gravitational forces in the system. **14.B** Use a simulation of a two-object system to produce data that can be analyzed to identify patterns to determine how changes in the mass or distance between the objects in the system affects the strength of gravitational forces between those objects in space.	**14.A Developing and Using Models; Systems and System Models** **When to check for understanding:** On day 1, when students develop initial models to explain the effect of changing size or location of one orbiting object in relation to another. **What to look/listen for:** • Referencing gravity as an important force in the system. • Identifying gravity as a force that would tend to pull objects downward toward the surface of Earth (when near Earth's surface). • Identifying where in the space above Earth and the Moon and between them gravitational forces would be found. This field-based thinking is similar to prior work done in *Magnets Unit*. **14.B Analyzing and Interpreting Data; Patterns** **When to check for understanding:** While students are using the computer interactive to complete the data table on the *Simulating a Two-Object System*, move around the classroom and listen in to student conversations. **What to look/listen for:** Look for students to identify the following relationships: • If the force of gravity between the two objects decreases (mass decreases or distance between objects increases) or the outer object moves faster, the outer object will fly away. • If the force of gravity between the two objects increases (mass increases or distance between objects decreases) or the outer object moves too slow, the outer object will crash into the inner object.
Lesson 15	**15.A.** Develop and map evidence from written and media sources to support the claim that the solar system formed from a disk of gas and dust, drawn together by gravity that was once chaotic but has become more stable over time.	**Obtaining, Evaluating, and Communicating Information; Stability and Change** **When to check for understanding:** When students create their comic book storyboards representing the formation of the solar system on *Comic Book Storyboard Showing the Formation of the Solar System*. As students work to build a class consensus model of the formation of the solar system. **What to look/listen for:** • The solar system started as a disk of gas and dust drawn together by gravity. • The Sun formed in the center of the disk, and the matter that was left over began to collect to form small planets. • The small planets collided many times over several millions of years, resulting in the creation of larger planets, asteroids, and comets. • The collisions became less common as objects in the solar system as the objects had stable orbits.

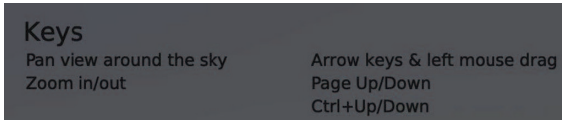
Lesson	Lesson-Level Performance Expectation(s)	Assessment Guidance
Lesson 16	**16.A** Compare and critique two arguments emphasizing the same evidence (images of galaxies) about the organization of systems in space. **16.B** Obtain and synthesize information across multiple sources about the organization of space systems in our universe from the human scale to the galactic scale.	**16.A Arguing from Evidence; Systems and System Models** **When to check for understanding:** Use the whole-class discussion of the Shapley-Curtis Great Debate as an opportunity to formatively assess students' ideas and respond in the moment to push student thinking. **What to look/listen for:** Look for students to notice that both models explain the evidence in different ways. Also look for students to seek out data related to how far away things are in space. **16.B Obtain, Evaluate, and Communicate Scientific Information; Systems and System Models; Scale, Proportion, and Quantity** **When to check for understanding:** During the Building Understandings Discussion after watching the *Powers of Ten* movie, use the whole-class discussion as an opportunity to formatively assess students' ideas and respond in the moment to push student thinking. **What look/listen for:** Look for students to articulate their ideas about how gravity organizes the universe into clumps of something surrounded by a vast expanse of nothing.
Lesson 17	**17.A** Develop a model of the universe that shows how gravity forces cause the patterns of motion and organization of objects in space systems at multiple scales.	**17. A Developing and Using Models; Systems and System Models; Scale, Proportion and Quantity** **When to check for understanding:** • As students are developing their models of the structure of the universe and our place in it in small groups on day 1. • As students contribute ideas to the class consensus model in whole group discussion on day 2. **What to look/listen for:** Look for students to include multiple scales and to be able to articulate the reasons why their model has the structure it does, referencing the role of gravity in each system. Specific guidance on more specific elements and interactions to look for is identified in the related assessment callout boxes.

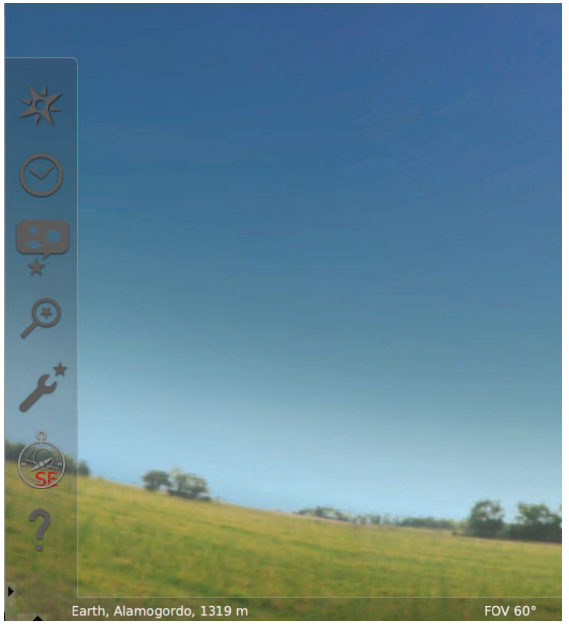
LESSON 2: TEACHER REFERENCE 1

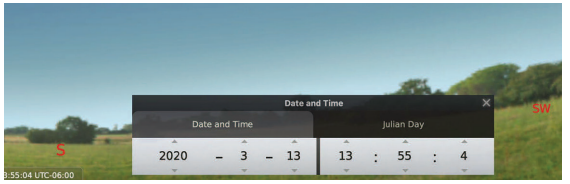
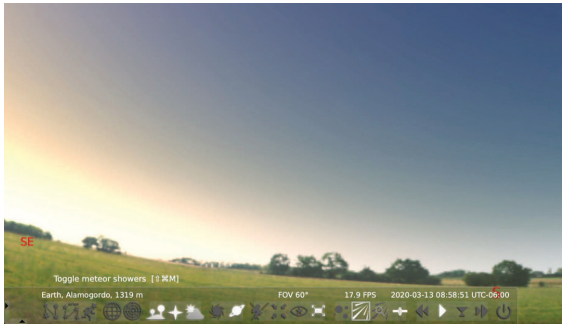
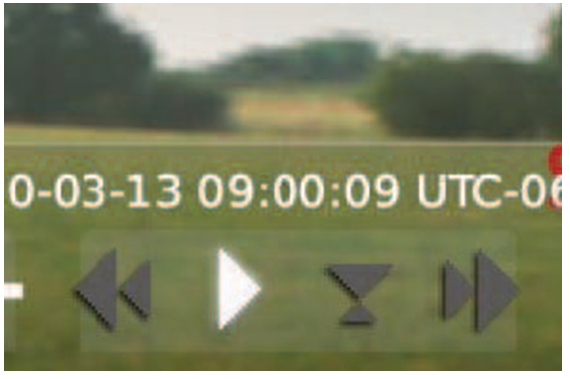
Stellarium Introduction Teacher Reference

Please see Stellarium Teacher Orientation video at https://youtu.be/VzxA9bUCZ-A

	Instructions	Screenshot
1.	Stellarium is free, open-source planetarium software. It is available for Windows, Linux, and macOS. There is also a Stellarium in-browser web application that can be accessed for free on desktop or mobile devices and could be a great resource for students. But, as of March 2020, this version has limited functionality, and we recommend that you download a desktop version for classroom use. A paid Stellarium mobile app is also available for Android and iOS.	 Stellarium
2.	Stellarium renders realistic views of the sky at any time or date from any place on Earth. It also allows the user to speed up time, giving students the opportunity to observe patterns in the sky over periods of hours to centuries and collect data that might otherwise be beyond the scope of the classroom.	 Stellarium

3.	You can download Stellarium software from Stellarium.org. Choose the version of the software (icons shown at the top of the page) that matches the operating system you are using.	 Stellarium
4.	Once the software is installed, you can adjust the view by zooming in and out and panning around the sky. You can pan by clicking and dragging with the left mouse button or by using the right and left arrow keys. You can zoom in and out by using the page up and page down keys or by pressing Ctrl+up arrow or Ctrl+down arrow. On a Mac, this is Command or the Apple key+up and down arrows.	 Stellarium
5.	Pan to face the southern horizon, and then zoom out so that you will be able to see the full arc of the Sun throughout the year. You will need to be able to see the “E” and “W” markers on either side of the screen in order to capture both sunrise and sunset on the summer solstice.	 Stellarium

6.	You can set your location by opening the Location window. To access this window, hover your mouse at the left boundary of the Stellarium window. A toolbar should appear. The top option, which looks like a compass, will open the Location window.	 Stellarium
7.	Click on the world map in the Location window to narrow the options to a smaller region. Scroll through the Location List until you find a nearby location and click on the city name. Then click the X in the top right to close the window.	 Stellarium

8.	The second icon down on the left toolbar, which looks like a clock, will bring up the Date and Time window. You can click on the arrows above and below the numbers to change the date and time to view. Note that the time uses the 24-hour day, so 1:00 p.m. is shown as 13:00:00.	 Stellarium
9.	In the Date and Time window you can make the simulation time pass hourly by clicking once on the number for hours and then using the keypad up and down arrows. Or you can speed up the simulation so that time passes more quickly on its own using the Increase time speed icon on the toolbar at the bottom of the screen. You will need to hover the mouse over the bottom boundary of the Stellarium window to make this toolbar appear.	 Stellarium
10.	The four icons to the left of the Quit icon on this bottom toolbar control the passage of time. The single, right-facing arrow will make time pass in real time (a rate of one hour per hour). The double, left-facing arrow will slow time by a tenth. The double, right-facing arrow will speed up time by ten. The hourglass shape will take you back to the current moment in time.	 Stellarium

11.	You can click around in the viewing window to bring up an information box about different objects in the sky. To close an information box at any point, you can right-click anywhere in the viewing window to make it disappear.	 Stellarium
12.	Set the date to January 1 and then speed up time to observe the path of the Sun. Adjust the view using pan and zoom if necessary until you are sure that you will be able to see the full arc of the Sun when you make observations in class. You are now ready to take observations for Lesson 2.	 Stellarium

Observing the Sun with Stellarium

Teacher Reference for Observing the Sun video at https://youtu.be/07_h5EEb8Gk

	Instructions	Screenshot
1.	Make sure you have oriented yourself to Stellarium using the Stellarium Orientation video at https://youtu.be/VzxA9bUCZ-A and/or *Stellarium Introduction Teacher Reference*. Press the hourglass button on the bottom toolbar to adjust the date and time to now. Make sure the right location is set and that time is moving at a normal rate by pressing the single, right-facing arrow.	 Stellarium
2.	Speed up time using the double, right-facing arrow. Click the arrow three times and ask students to observe the path of the Sun. As the Sun sets, reset the rate of time by clicking the single, right-facing arrow and ask students to record their observations on *Observations of the Sun: Location* _____.	 Stellarium
3.	Move quickly through the night by using the time arrows or clicking the double, right-facing arrow four times. At sunrise, again reset the rate of time to normal with the single right-facing arrow and ask students to record their observations on *Observations of the Sun: Location* _____.	 Stellarium

4.	Tell students to next sketch the approximate path of the Sun through the sky as it moves from sunrise to sunset. Tell them you are going to speed up time and let them observe the path for a couple of days so they can get it right. Then click four times on the double, right-facing arrow, and let a couple of days pass. Students should record only one observation at this point but can use the multiple passes to refine their data. Then slow things down again with the single, right-facing arrow.	 Stellarium
5.	Tell students that you are going to skip ahead a couple of months so that we can take observations at another time of year. If you have chosen to take five observations at three-month intervals (seasonally), skip ahead three months using the date/time dialogue in the bottom right, and repeat the previous three steps. If you have chosen to take seven observations at two-month intervals (twice per season), skip ahead two months and repeat the previous three steps.	 Stellarium
6.	Repeat the previous step (step 5) for the number of observations you would like your class to make.	 Stellarium

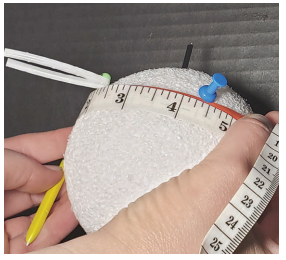
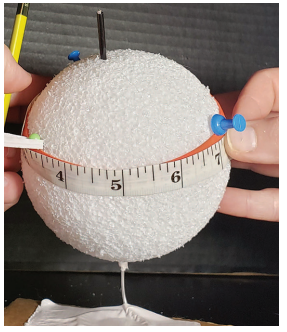
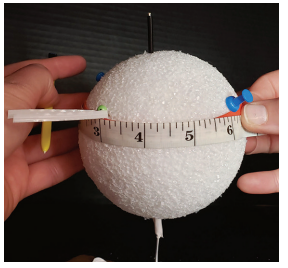
LESSON 3: TEACHER REFERENCE 2

Data from NOAA websites

Year	Date	Sunrise	Sunset	Solar elevation at noon
For this year: 1000	March 20	06:39	18:47	45.33 degrees
	June 20	05:03	20:04	64.14 degrees
	September 22	06:21	18:32	44.37 degrees
	December 21	07:55	17:15	22.95 degrees
For this year: 1500	March 20	06:39	18:46	45.27 degrees
	June 20	05:04	20:05	64.29 degrees
	September 22	06:21	18:32	44.42 degrees
	December 21	07:53	17:14	22.91 degrees
For this year: 2000	March 20	06:37	18:47	45.51 degrees
	June 20	06:06	21:06	64.48 degrees
	September 22	07:22	19:31	44.08 degrees
	December 21	07:52	17:13	22.91 degrees
For this year: 2500	March 20	06:37	18:46	45.4 degrees
	June 20	05:07	20:07	64.61 degrees
	September 22	06:23	18:31	44.12 degrees
	December 21	07:51	17:12	22.87 degrees

Example Modeling the Earth-Sun System Data

If your students are not able to complete physical modeling on *Modeling the Earth–Sun System* themselves, give them the following sample data to use.

	Position 1 or March 20	Position 2 or June 20	Position 3 or September 22	Position 4 or December 21
Length of observer's path through daylight (inches)				
Approximate path of the Sun in the sky from the observer's perspective	 Stellarium	 Stellarium	 Stellarium	 Stellarium

LESSON 3: ANSWER KEY

Key to Mapping the Model to the Earth–Sun System

Feature of the representation ...	*is like this feature of the real world ...*	*because ...*	*and is not like it because ...*
Light bulb	Sun	It gives off light.	The Sun is much bigger and farther from the Earth. The Sun is also really hot.
Large foam ball on a stick.	Earth and its axis	They are both round and go around the Sun.	The Earth is actually much bigger than the sphere, but not as big as the Sun. The Earth is also much farther away from the Sun.
Round pushpin (with twist-tie around it)	Person on Earth	It is in the Northern Hemisphere, it moves as the Earth spins, and it can see the Sun during the day.	Thumbtack is bigger compared to the sphere than a human compared to the Earth.
Rubber band	Path the person follows over 24 hours (latitude line)	It is showing how the person (on Earth) would move over time.	There isn't an actual line on Earth.
Twist-tie	Arm pointing at the Sun	It is long and it can move.	The twist-tie doesn't have fingers and can't move with the changing Sun unless we move it.
Light shining on the sphere	Daytime	Light from the Sun/lamp shines on the surface.	Sunlight is hot, and there is a lot more of it. Also because the Earth is much bigger than the sphere, the sunlight has a lot more surface to hit.
Shadowed side of the sphere	Nighttime	The light from the Sun/lamp can't get to the surface.	There is a little bit of light on the sphere still because the light bounces off the walls of the room, and light comes in through the window.

What causes the seasons in Australia and why are they opposite of our seasons?





Jessie told us in the *Reading-Podcast: Jessie Ferrari - Wombat Season* that in Australia there are many different seasons, such as Wombat season and Biderap season. During the Wombat season, Wombats emerge from their dens, which is from April through July, the days are short, nights are long, and the temperature is cooler. During Biderap season, when brown butterflies emerge, which is in January and February, the days are longer, nights are shorter, and the temperature is hotter.

Examine the data below, which shows the average low and high temperatures in Melbourne, Australia.

Month and season	Average high temp. in Melbourne, Victoria, Australia	Average low temp. in Melbourne, Victoria, Australia
July, Wombat season	57°F (13.9°C)	45°F (7.2°C)
January, Biderap season	79°F (26.1°C)	60°F (15.5°C)

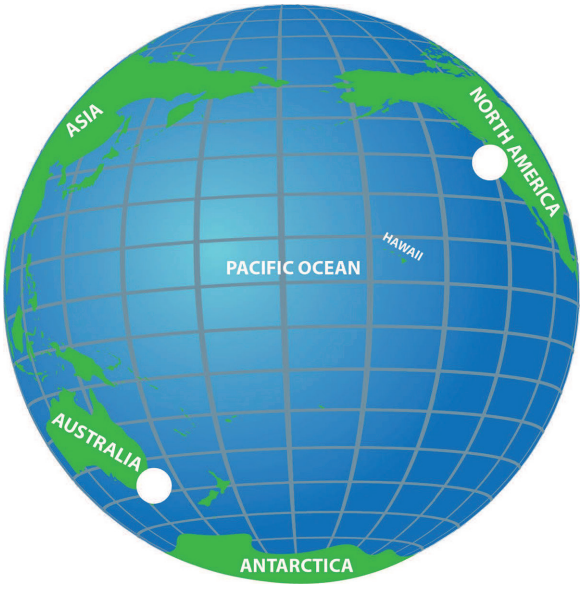
1. What causes seasonal temperature variation between Wombat season (July) and Biderap season (January) in Australia?

Using words, and/or pictures, support your explanation using the temperature data above, your Gotta-Have-It Checklists, and by completing the model below.

Wombat season: July		Biderap season: January
		

We all live on the same Earth, yet at the same time of year people might have very different experiences of the climate in different places on Earth. Professor Medupe and Jessie both mentioned in their podcasts that the cooler months where they live happen during what we would call summer or the warmer months in the Northern Hemisphere. For example, in July someone in the United States might be experiencing warmer weather and long days while a person in Australia might be experiencing really colder weather and short days. See the data table below for example temperatures in the Northern and Southern Hemispheres during January and July.

Month	**Average high temp. in Melbourne, Victoria, Australia (Southern Hemisphere)**	**Average high temp. in Seattle, Washington, United States (Northern Hemisphere)**
July	57°F (13.9°C)	72°F (22.2°C)
January	79°F (26.1°C)	47°F (8.3°C)



2. Why do the warmer months in the United States occur at the same time as the cooler months in Australia and the cooler months in the United States align with the warmer months in Australia?

LESSON 4: ANSWER KEY 1

Key for Modeling Sunlight Angles

Making Sense

1. Fill in the data table by following these steps:
   a. Count the number of squares on each image. In the table, write the number of squares that the light covers for each condition. (Decide how you want to count partial squares, and be consistent. You could drop them all out, count them all, or estimate them to the nearest fraction.)
   b. Look for the wattage on the flashlight you are using. This number describes the rate of energy output from light of the flashlight every second, in watts. Write this number in the "Energy from the flashlight" column of the data table, in both rows. If you cannot find the wattage of the flashlight, assume that the rate of energy output of the light is about 5 watts.
   c. Calculate how much energy from light is concentrated on each square of graph paper by dividing the value in column 1 by the value in column 2 and recording the result in column 3.

Energy from light (column 1) ÷ Area (column 2) = Energy per square (column 3)

Time of year	Energy from the flashlight (measured in watts)	Area (total number of squares)	Energy per square of graph paper (watts/square)
Sun in the sky: June	5	29.5	0.169
Sun in the sky: March & September	5	49	0.10
Sun in the sky: December	5	50.5	0.099

2. How do the angles of the pipe cleaners relate to the solar elevation measurements we made?

They aren't exactly the same but are close to the measurements and represent the path of the Sun in the sky.

3. What pattern do you see in the energy from light per square of graph paper data?

The higher the Sun is in the sky, the light energy per square of graph paper increases. The lower the solar elevation, the light energy per square of graph paper decreases.

4. What relationship is there between the angle of the Sun in the sky, the watts per square, and temperatures on Earth? Why?

The higher the angle, the more watts per square of graph paper. This is because when Earth is tilted towards the Sun in the summer, the solar elevation is higher so Earth gets more energy from the Sun. Because Earth gets more light energy from the Sun, Earth's surface heats up more so the temperatures are hotter.

LESSON 4: ANSWER KEY 2

What causes the seasons in Australia and why are they opposite of our seasons?

The following scoring guidance provided can help you identify different ideas that students should (or could) include in their responses.

- If several of the ideas marked with a • are missing from a student's response, this may indicate the student has not mastered the science ideas or that the student may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether the student is struggling with a science practice or science idea, or both.
- If all or almost all of the ideas marked with a • are present in a student's response, this may indicate that the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.

Jessie told us in the *Reading-Podcast: Jessie Ferrari - Wombat Season* that in Australia there are many different seasons, such as Wombat season and Biderap season. During the Wombat season, Wombats emerge from their dens, which is from April through July, the days are short, nights are long, and the temperature is cooler. During Biderap season, when brown butterflies emerge, which is in January and February, the days are longer, nights are shorter, and the temperature is hotter.





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What causes seasonal temperature variation between Wombat season (July) and Biderap season (January) in Australia?

Support your explanation using the temperature data above, your Gotta-Have-It Checklists, and by completing the model below.

Wombat season: July		Biderap season: January
		

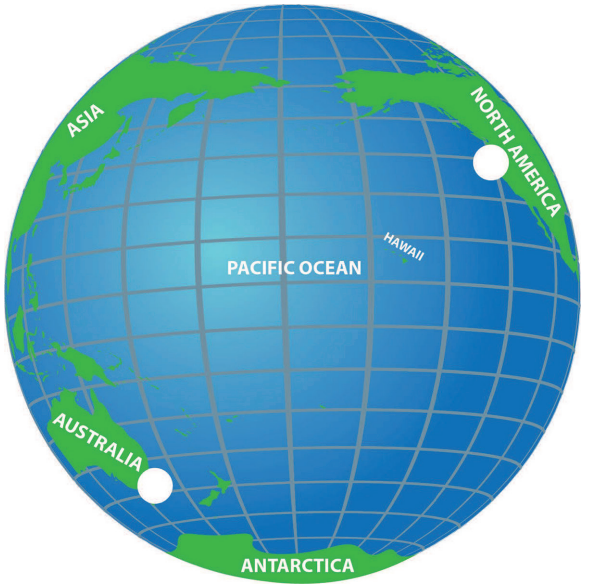
Student explanations should include:

- When it is Wombat season (July), the Southern Hemisphere is tilted away from the Sun.
  - Since the Southern Hemisphere is tilted away from the Sun, they would experience lower amounts of daylight and longer amounts of night.
  - When the Earth is in this position, the angle of the Sun is lower. The sunlight hits the Earth less directly in the Southern Hemisphere. When this happens, it causes cooler temperatures than other times of year when the sunlight hits the Earth more directly.
- When it is Biderap season (January), the Southern Hemisphere is tilted towards from the Sun.
  - Since the Southern Hemisphere is tilted towards the Sun, they would experience higher amounts of daylight and shorter amounts of night.
  - When the Earth is in this position, the angle of the Sun is higher and the sunlight hits the Earth more directly in the Southern Hemisphere, when the sunlight hits more directly, it causes warmer temperatures than other times of year when the sunlight hits the Earth less directly.

We all live on the same Earth, yet at the same time of year people might have very different experiences of the climate in different places on Earth. Professor Medupe and Jessie both mentioned in their podcasts that the cooler months where they live happen during what we would call summer or the warmer months in the Northern Hemisphere. For example, in July someone in the United States might be experiencing warmer weather and long days while a person in Australia might be experiencing really colder weather and short days. See the data table below for example temperatures in the Northern and Southern Hemispheres during January and July.

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January	79°F (26.1°C)	47°F (8.3°C)

Why do the warmer months in the United States occur at the same time as the cooler months in Australia and the cooler months in the United States align with the warmer months in Australia?



Sample Explanation:

The Earth's tilt causes there to be differences in the intensity of the light received by different parts of the Earth at certain times.

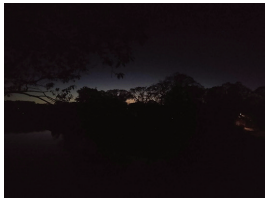
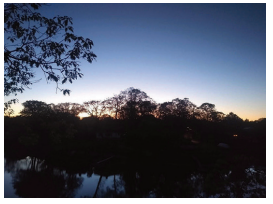
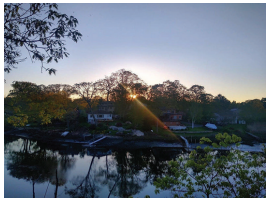
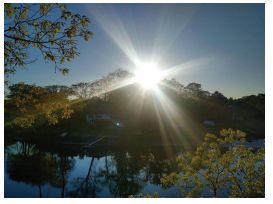
- For example, when it is July and 57 degrees in Australia, the light received is more spread out so there is less light energy. This is because the solar elevation in the Southern Hemisphere is lower than it is in January. In the Northern Hemisphere, the Earth is tilted more towards the Sun in July. This means that the solar elevation in the sky is higher, so the light received is more direct and causes there to be more light energy received in that place on Earth. This causes the surface to heat up more, leading to higher temperatures.
- When it is January in Australia, the Southern Hemisphere is tilted more toward the Sun than the Northern Hemisphere. This leads to the solar elevation in the Southern Hemisphere being higher compared to the Northern Hemisphere. So the light received there is more direct, and this causes there to be more light energy to reach the surface. This causes the surface to heat up more, leading to higher temperatures in the Southern Hemisphere compared to the Northern Hemisphere.

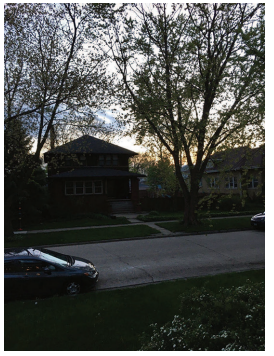
Student explanations should include the following:

- Tilt results in differences in the amount of sunlight on different parts of the Earth's surface at different times of the year.
- Solar elevations are opposite in the Northern and Southern Hemispheres at the same time (July or January).
- Light energy amounts reaching the surface are directly related to solar elevations:
  - higher solar elevation = higher light energy; and
  - lower solar elevation = lower light energy.
- Temperature is directly related to light energy amounts reaching the surface.

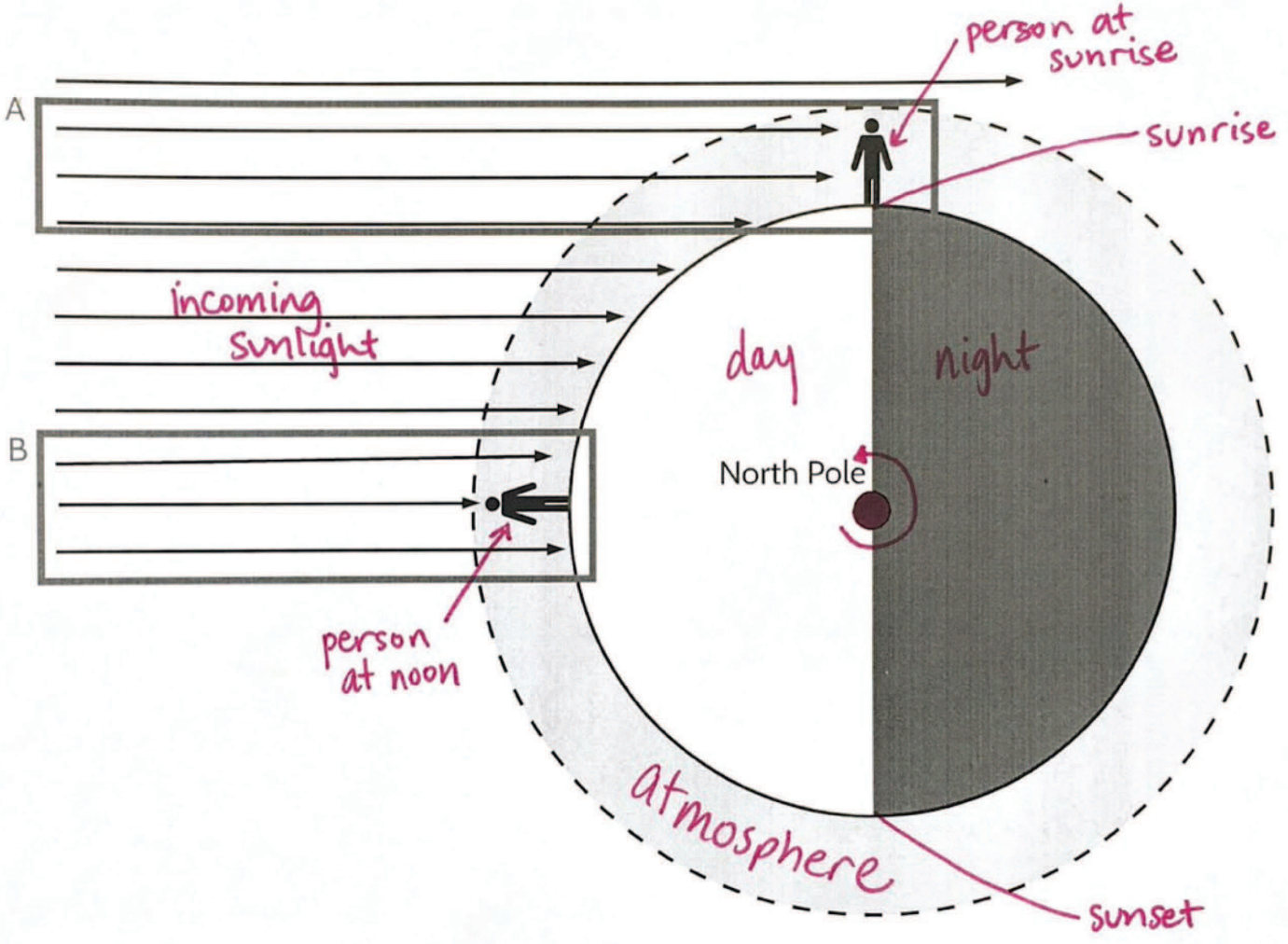
Examples of Sun Brightness Data

These data are provided simply as examples of what you and your students might collect. You may notice, like we did, that cellphone cameras may automatically adjust for brightness and color.

Example data from East Haven, CT, on May 13, 2021, over 2 hours				
60 min before sunrise 4:30 a.m. 90° (east)	30 min before sunrise 5:00 a.m. 90° (east)	at sunrise 5:30 a.m. 90° (east)	30 min after sunrise 6:00 a.m. 90° (east)	60 min after sunrise 6:30 a.m. 90° (east)
				
0 lux	3.3 lux	412 lux	3240 lux	53500 lux

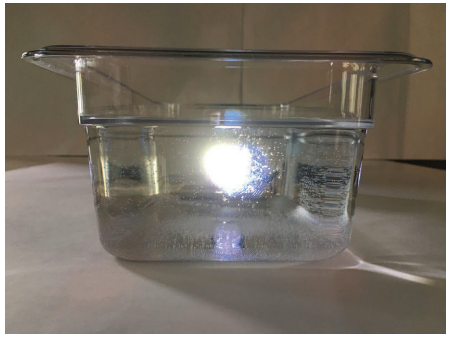
Example data from Brookfield, IL, on May 5, 2021, over 1 hour				
30 min before sunset 7:25 p.m. 315° (northwest)	15 min before sunset 7:40 p.m. 315° (northwest)	at sunset 7:55 p.m. 315° (northwest)	15 min after sunset 8:10 p.m. 315° (northwest)	30 min after sunset 8:25 p.m. 315° (northwest)
				
5491 lux	2130 lux	956 lux	76 lux	6 lux

Teacher-Annotated Version of Comparing Sunlight at Sunrise vs. Midday

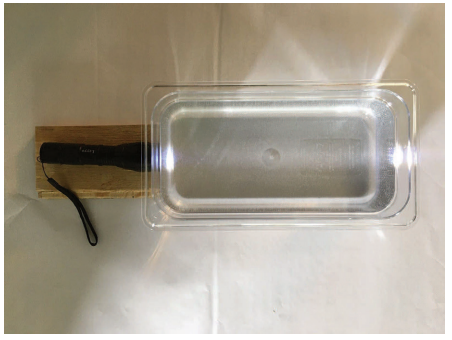


Sample Investigation Images

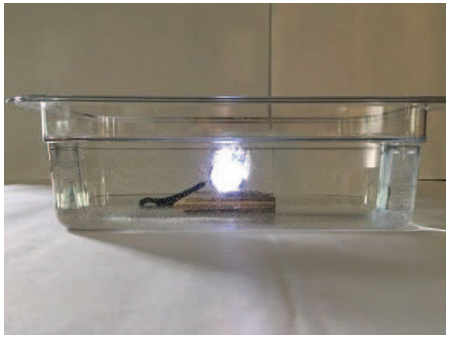
Plain water



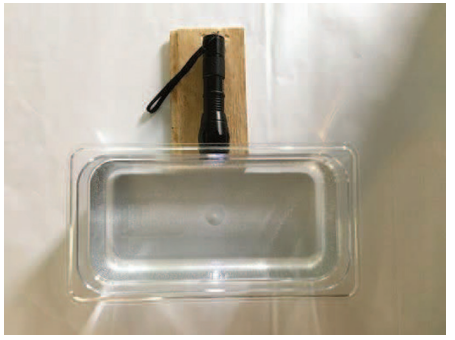
(A) lengthwise at eye level



(A) lengthwise from above



(B) widthwise at eye level



(A) widthwise from above

Water with ¼ tsp milk powder added



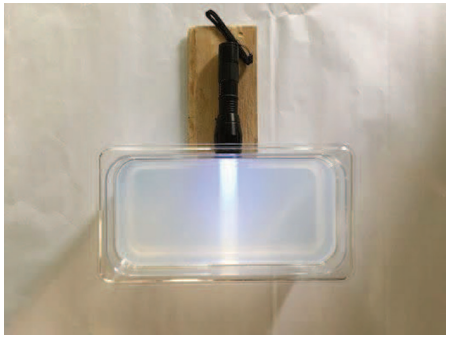
(A) lengthwise at eye level



(A) lengthwise from above



(B) widthwise at eye level

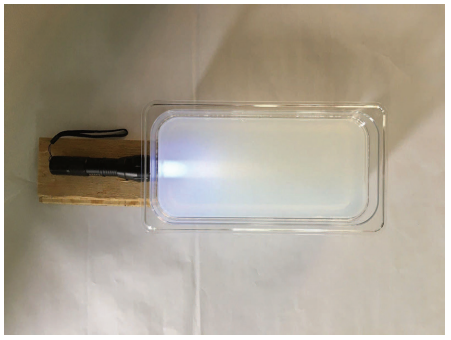


(A) widthwise from above

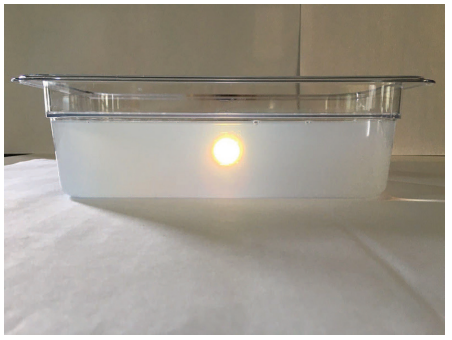
Water with another ¼ tsp milk powder added (½ tsp total)



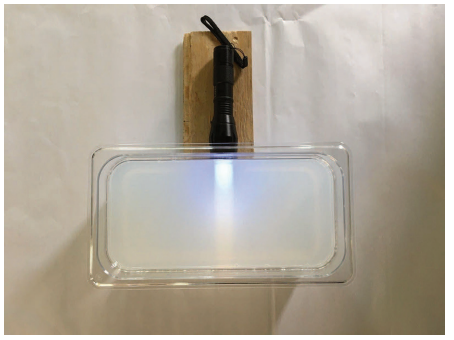
(A) lengthwise at eye level



(A) lengthwise from above



(B) widthwise at eye level



(A) widthwise from above

LESSON 10: ANSWER KEY

Investigation Elements Map, Predictions, and Results

Directions: Work with your class to fill in the table as you map each part of the investigation set-up to the real-world phenomenon we are wondering about.

This part in our investigation...	is like this part in the real world...	because...
flashlight	the sun	They both give off light (and some give off heat).
water	the gasses of our atmosphere	Both gas particles in the atmosphere and water molecules in the container move freely and have some space between them for other particles.
milk powder	the particles in the atmosphere that are larger than molecules	The atmosphere has dust, pollution, water droplets, ice crystals, etc. in it.
adding additional milk powder to the water	areas (or times) in the atmosphere where or when the particles are more dense	Some locations have more dust, smoke, pollution, etc. around them sometimes.
the color of light from the flashlight (before it reaches the liquid)	the color of light from the Sun before it reaches Earth's atmosphere	They both are bright white.
length of the container of liquid	the longer path of light through the atmosphere at sunrise or sunset	The amount of atmosphere the Sun passes through depends on the particular time of day. At sunrise/sunset we're looking at the Sun through more/a longer atmosphere.
width of the container of liquid	the shorter path of light through the atmosphere at noon	At noon we are looking at the Sun through less/a shorter amount of atmosphere.

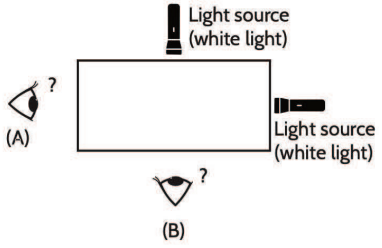
Directions:

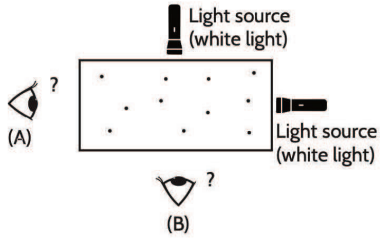
1. Record your predictions in the following table describing what you expect to see in terms of brightness ***and*** color.

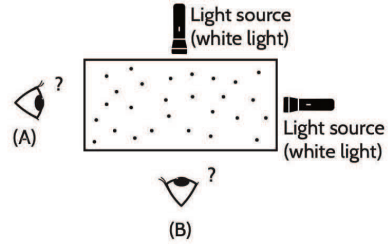
- Answers will vary, but some sample predictions are provided in the following table.

2. Record your results as you find them in the following table describing what you do see in terms of brightness ***and*** color.

- Sample responses are provided in the following table.

What color and brightness do we see through the simulated atmosphere at different positions/times of day?			
Investigation condition	**Scenario**	**Prediction**	**Results**
 1) plain water - just gasses	(A) from eye level at sunrise/sunset from Earth	Will the light look blue or green, like underwater? Still bright, though.	The light is bright enough to make me see spots (like when I look at it without the water). The light is white, the same color it is without the water.
	(A) from above at sunrise/sunset imaginary cross-section view	Will the light change direction like we saw with the straw in the glass of water in the *One-way Mirror Unit*?	I can see the light hitting the wall of the container where the flashlight is and the opposite wall of the container. It's still white, but I can't really tell how bright it is.
	(B) from eye level at noon from Earth	There's not as much water there to go through, so maybe the light won't change much—still bright and white?	The light is bright enough to make me see spots (like when I look at it without the water). The light is white, the same color it is without the water.
	(B) from above at noon imaginary cross-section view	I predict the water and light will look bright and white or clear.	I can see the light hitting the wall of the container where the flashlight is and the opposite wall of the container. It's still white, but I can't really tell how bright it is.

What color and brightness do we see through the simulated atmosphere at different positions/times of day?			
Investigation condition	**Scenario**	**Prediction**	**Results**
 2) milk powder + water - atmosphere	(A) from eye level at sunrise/sunset from Earth	Based on what we see in the sky at sunset, I predict the light will look dimmer and orange.	The light is orange! It's dimmer than when the water was clear, too. The milky water around the orange "Sun" doesn't look plain white, either, but it's hard to name the color it is.
	(A) from above at sunrise/sunset imaginary cross-section view	Maybe the light will look orange and dimmer there, too, like the clouds at sunset.	The light looks whitish-blue near the flashlight, but I can see it kind of fading to orange as it travels through the milky water. The light definitely gets dimmer as it travels. The milky water is bluer near the flashlight and oranger at the opposite end of the bin.
	(B) from eye level at noon from Earth	Based on what we see in the sky at noon, I predict the light will look bright and yellowish.	The light looks whitish. It's brighter than view A, but not nearly as bright as in the plain water. The milky water looks whitish.
	(B) from above at noon imaginary cross-section view	Maybe the light will look yellow and brighter there, too, and the "atmosphere" will look bluish like the sky during the day.	I'm seeing the same things as (A)-above: whitish-blue to orange in the light and surrounding liquid, but the light doesn't get as dim on the opposite-the-light orange end.

What color and brightness do we see through the simulated atmosphere at different positions/times of day?			
Investigation condition	**Scenario**	**Prediction**	**Results**
 3) additional ¼ tsp milk powder + water atmosphere with more particles in it	(A) from eye level at sunrise/sunset from Earth	The light will be very orange and very dim.	The light is reddish-orange and pretty hard to see. The milky water "atmosphere" looks cloudier.
	(A) from above at sunrise/sunset imaginary cross-section view	We'll see even more blue "atmosphere" around the light source than with ¼ tsp milk powder, and darker and dimmer orange away from it.	We can see the same color change (from whitish-blue to orange), but it seems to happen closer to the light source, and by the end of the container, it's hard to see the light at all.
	(B) from eye level at noon from Earth	The light will be more orange than it was with only ¼ tsp milk powder. It will be dim, but not as dim as "sunset" was.	The light is orange and not as dim as the "sunset" view, but dimmer than "sunset" when we only had ¼ tsp of milk powder in it. The "atmosphere" around the light looks whitish-blue.
	(B) from above at noon imaginary cross-section view	We'll see less blue "atmosphere" around the light source than in the "sunset" view, and darker and dimmer orange away from it.	The light looks similar to the "above noon" view with only ¼ tsp of milk powder, but the bluish-white fades to orange sooner, and there seems to be more orange overall (though the "atmosphere" near the flashlight still looks bluish).

Making sense of the data:

1. How does the amount of the simulated atmosphere (the distance the light must pass through and/or the density of the particles in it) affect the ***brightness*** of the light from the simulated sun after the light travels through it?

The longer the path the light travels through the atmosphere, the dimmer it gets.

2. How does the amount of the simulated atmosphere (the distance the light must pass through and/or the density of the particles in it) affect the ***color*** of light from the simulated sun after the light travels through it?

The longer the path the light travels through the atmosphere, the more orange it gets.

3. Based on what you could see from the "imaginary cutaway" view of the atmosphere, what do you think is causing the changes we see when viewing light through the atmosphere?

Answers will vary, but may include the following ideas:

- The light is interacting with the simulated atmosphere somehow; something about the particles in the atmosphere is affecting the light.
- Different colors of the light are interacting with the "atmosphere" differently; some get through so we can see them at the "end" (orangish color), but some don't (colors other than the orange that is getting to our eyes).

Preparing for the Rainbow Lab

Instructions	Example

1. Obtain 8 copy paper boxes and prepare them for the 8 lab stations as follows:
   - On the bottom of each box tape two pieces of white paper, one with an X drawn across it.
   - Tape a copy of *Rainbow Lab Station Card* to the side of each copy box at each lab station.
   - Only the 2 boxes at both of the #3 stations (with the mirror in the bowl) need lids.



2. On the inside of each box opposite the X place a small block (a book will do), about 1–2 inches thick. This block will support a flashlight and allow students to be handsfree for part of the investigation. (You will need a total of 8 blocks/books, one in each box.)

   Check the batteries in each of your 8 flashlights, then place one flashlight on the block in each box pointing, as shown in the photo here. Have spare batteries on hand in case some run out during class.



3. Create duplicates of each of the following 4 stations, possibly in rows on opposite sides of the room to help with traffic flow. (Students will visit each of the 4 stations, not all 8). When you set the stations up, place the following items at each station next to the box, as shown in the images on the left. When students arrive at each station, they will make predictions and then set the object inside the box, as shown in the images on the right.

Station 1: A round glass tumbler filled with water





Station 2: A hexagonal glass or jar filled with water and the lid screwed on tightly so students can move it around without spilling





Station 3: A shallow clear glass bowl with a mirror set in at an angle. Fill the bowl about ⅔ full of water. Provide a lid at this station to view reflected light.





Station 4: A triangular prism, which students will stand vertically in the box

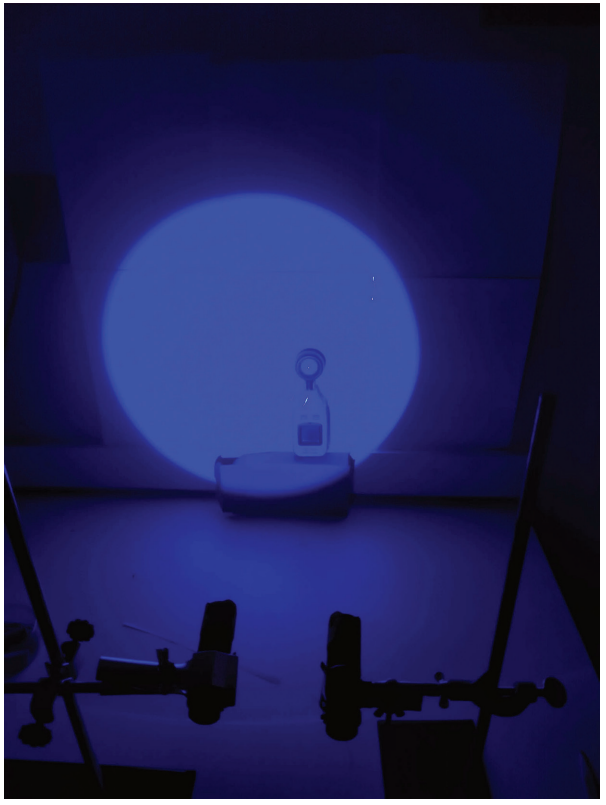




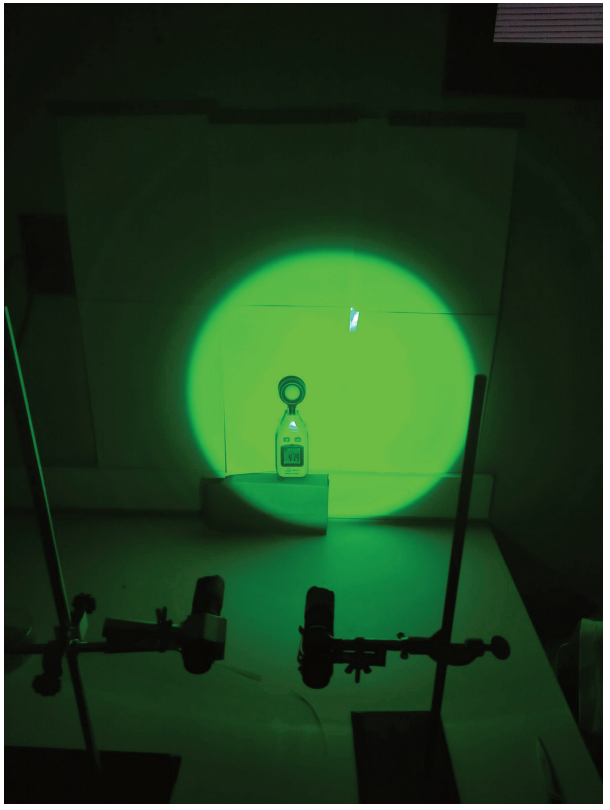
4. During this lab, students will visit the 4 stations (half of the class cycling through each group of 4 stations) and have 3–4 minutes at each station to make predictions and then figure out how light interacts with the object inside the box.

Sample Images: Combining Light Demonstration

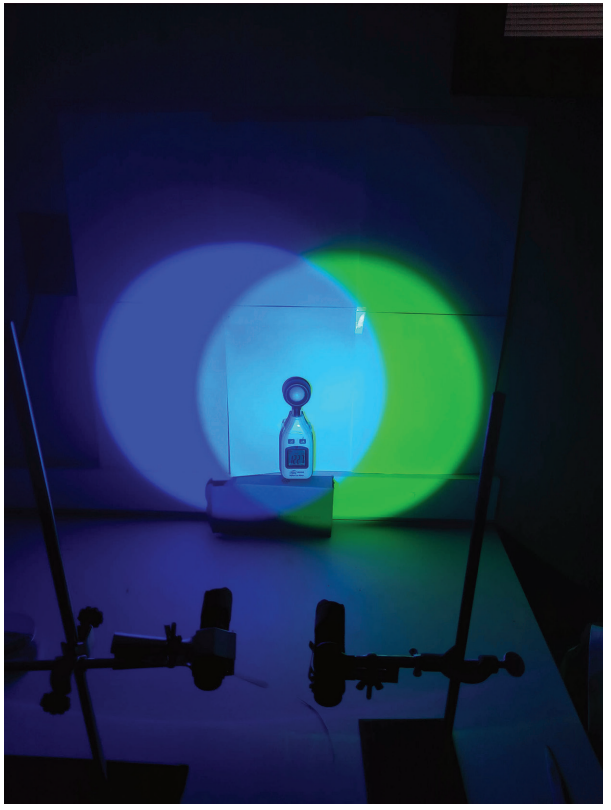
The following example photos and light meter readings are provided for your reference. Note that your results may vary depending on the strength of your flashlight bulbs and batteries, distance from the flashlights to the light meter, and ambient light in the room.



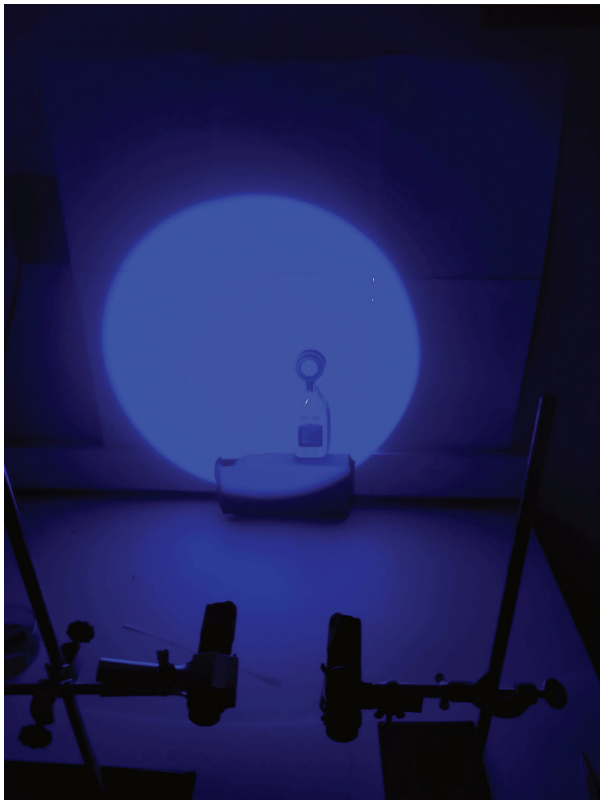
Blue alone
811 Lux



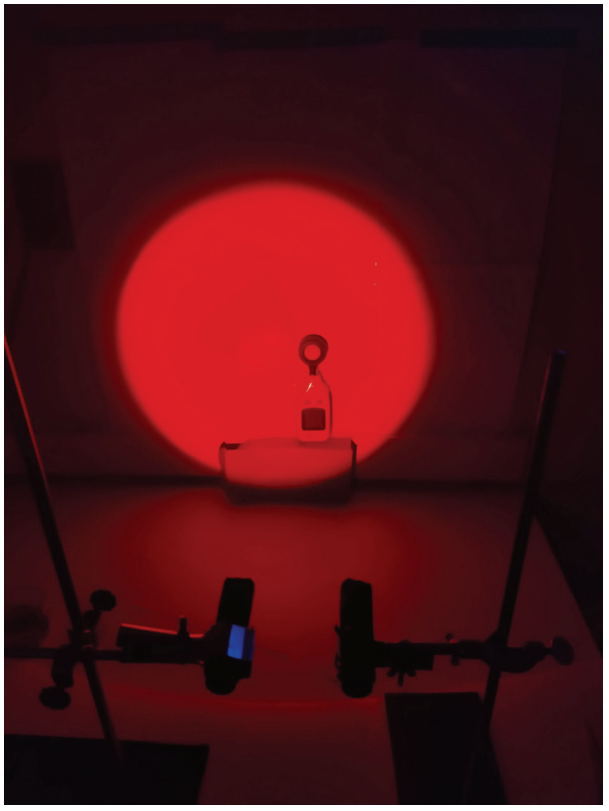
Green alone
584 Lux



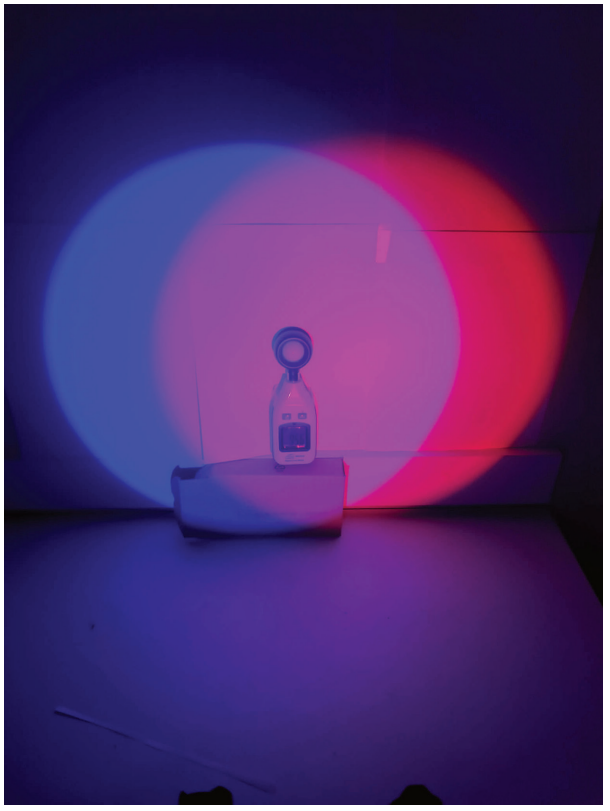
Blue + green
1509 Lux



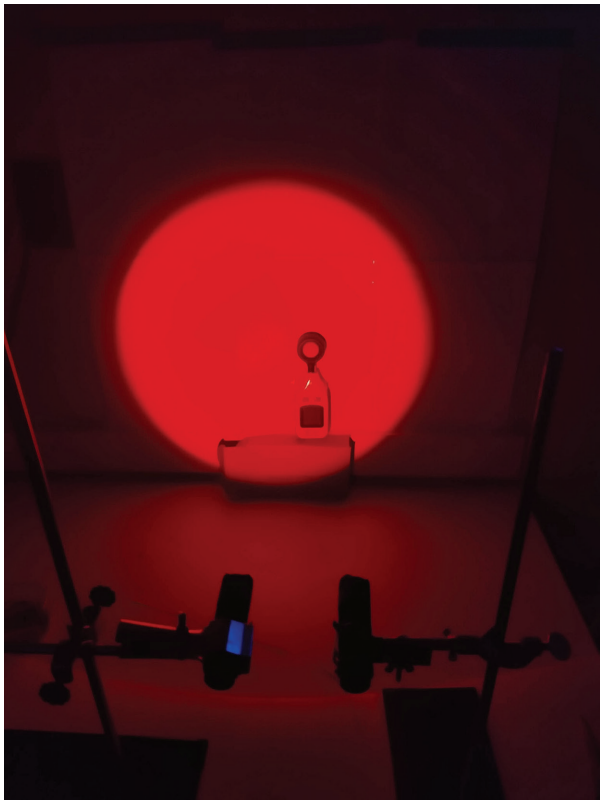
Blue alone
811 Lux



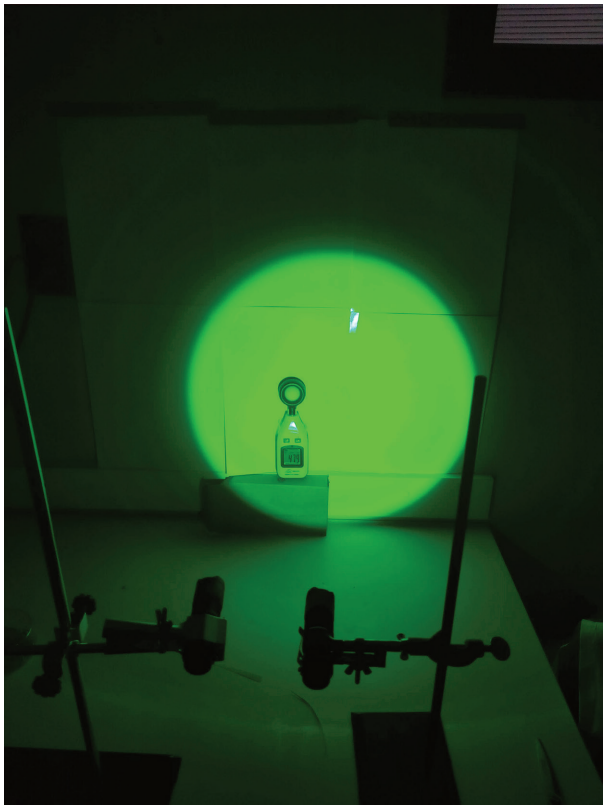
Red alone
164.3 Lux



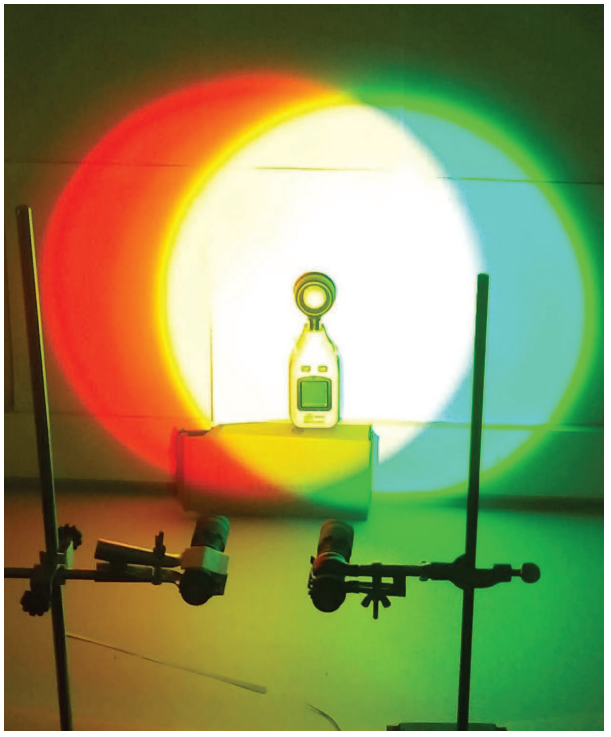
Red + blue
1002 Lux



Red alone
164.3 Lux



Green alone
584 Lux



Red + green
718 Lux



Red + blue + green
1789 Lux

Suggested Prompts for the Rainbow Lab Investigation

At each lab station and for each lab group, prompt observations by asking focusing questions around the key observational data sets. Some suggestions for each data set are below.

Path of light

- Where is your light source?
- Which direction is the light traveling when it leaves the light source?
- Does it keep traveling in that direction? Does it change course?
- Where else did the light go?
- What happened to the light to get it to appear there?

Color changes

- What color was the light at the light source?
- Did the light stay white, or did it change?
- What colors did you notice? Where did they come from?
- Did you see all of the colors of the rainbow?
- What did you do to see more colors? Less?

Brightness

- Did the reflected light seem as bright as the original white source?
- Could you see some colors more brightly?
- Which colors appear brighter?
- Which colors appear dimmer?
- Were there any colors you couldn't see at all?

Explaining Fishing Related-Phenomena

Part 1: People who fish often choose different lures to catch fish so that they can bring the fish to the surface to eat or sell. Different fish live at different depths below the surface of the water. In order for a lure to work well, the fish first needs to be able to clearly see it. If the fish can't see the lure, then it will not bite the hook and the person who is fishing will not get food to feed their family or sell to the fish market.



Individually, make a prediction: Do you think every color that you could use in making fishing lure will be equally visible many feet below the surface of the water? Why or why not?



_____

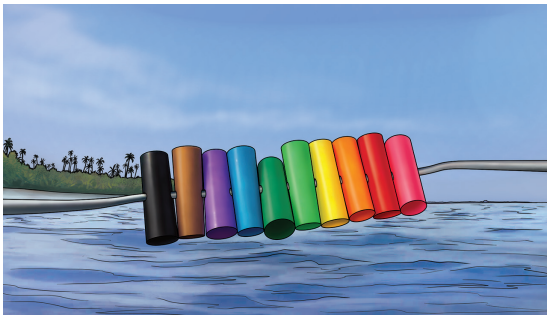
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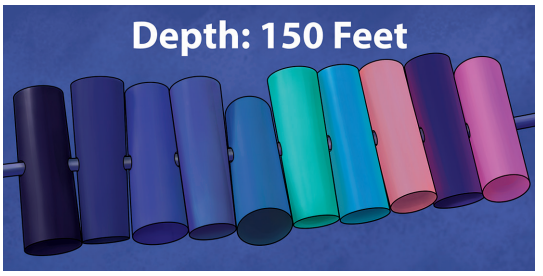
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As a class: Watch the video of the different color marker caps shown in the image to the right as they are brought deeper and deeper below the surface of the water.

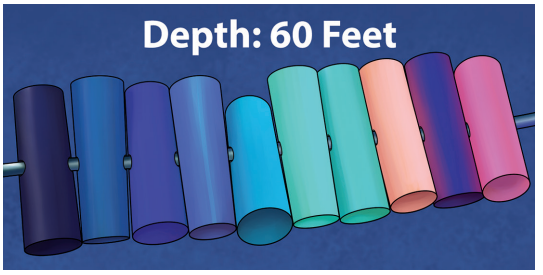


With a Partner:

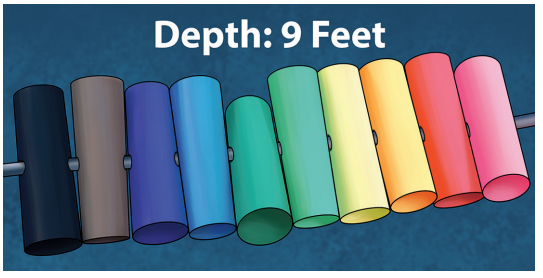
2. Use the results of the video to identify colors for a fishing lure that would be *best* to use for trying to catch fish that are 150 feet below the surface.



3. Use the results of the video to identify colors for a fishing lure that would be *bad to* use for catching fish that are 150 feet below the surface.



4. As sunlight travels through greater and greater amounts of liquid water, what colors of that light is it absorbing more quickly than others?



5. As sunlight travels through greater and greater amounts of liquid water, what colors of that light is it transmitting through it more easily than others?

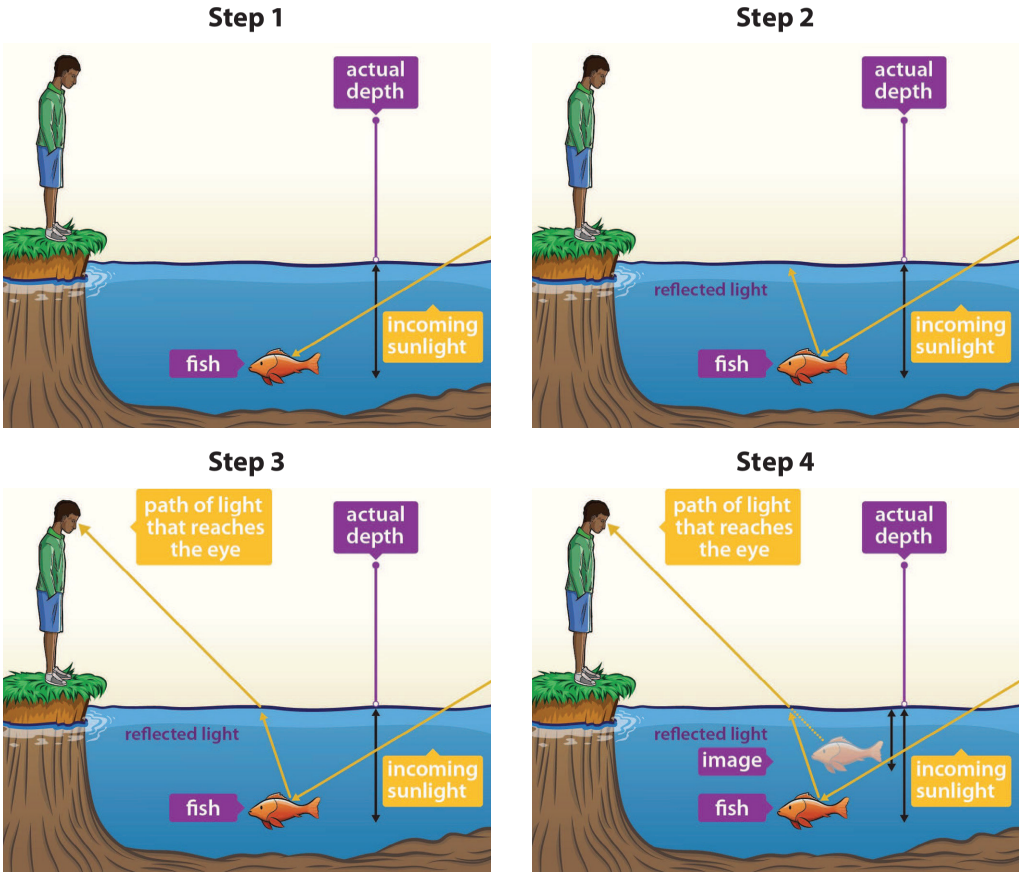


On Your Own:

6. Using words and/or pictures, show and explain the ways that the matter that the light is passing through is causing changes in the color and brightness that are similar to how the atmosphere causes changes in sunlight that passes through it:

7. Using words and/or pictures, contrast how matter affects the brightness and color of light passing through water differently than it affects light passing through the atmosphere.

Part 2: Some fishers do not use lures but use spears to catch fish by looking through the water and then spearing the fish. This is not easy to do because it is hard to see the fish. One issue is that the fish does not appear to be in the spot it actually is under the water! The images below show a model that a group of students developed to explain how light traveling through and out of the water affects the apparent position of fish in the water.



8. What is similar about how light interacts with the matter it passes through in this model compared to the results from your class investigations?

9. What is different about how light interacts with the matter it passes through in this model compared to the results from your class investigations?

10. Make a prediction: Do you think an object's depth below the surface would affect how much the apparent position of that object shifts for the observer? Explain your reasoning.

11. Describe an investigation you could design and carry out to test your prediction from question.

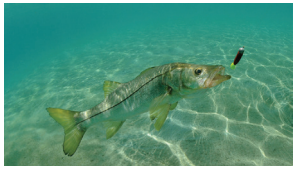
LESSON 12: ANSWER KEY

Explaining Fishing-Related Phenomena

Scoring Guidance: The scoring guidance provided below uses a + notation that can help you identify different ideas that students should (or could) include in their responses.

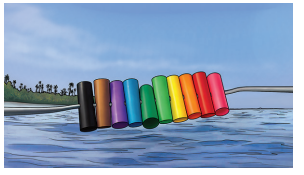
- If several of the ideas marked with a + are missing from a student's response, this may indicate the student has not mastered the science ideas or may be struggling to bring those ideas together in a written explanation or model. Additional probing of their thinking can provide insight about whether they are struggling with a science practice, science idea, or both.
- If all or almost all of the ideas marked with a + are present in a student's response, this may indicate the student has mastered the science ideas and is able to use them in a written explanation or explanatory model.
- If the ideas marked with a ++ are present in a student's response, this indicates that they are bringing a deeper understanding of the science ideas or a deeper engagement with the practice to their response. Responses should not be marked off if ideas marked with a ++ are not present in their response.

Optional Student Choice: Allow your students to choose the modality for communicating their thinking. They can explain the phenomenon through written words, in pictures, or orally. Guidance is provided based upon writing; however, these same ideas could be communicated orally or in pictures.



Part 1: People who fish, often choose different lures to catch fish so that they can bring the fish to the surface to eat or sell. Different fish live at different depths below the surface of the water. In order for a lure to work well, the fish first needs to be able to clearly see it. If the fish can't see the lure, then it will not bite the hook and the person who is fishing will not get food to feed their family or sell to the fish market.

Individually, make a prediction: Do you think every color that you could use in making fishing lure will be equally visible many feet below the surface of the water? Why or why not?



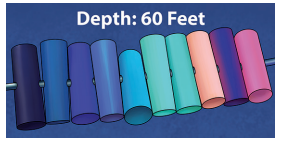
As a class: Watch the video of the different color marker caps shown in the image to the right as they are brought deeper and deeper below the surface of the water.

With a Partner:



2. Use the results of the video to identify colors for a fishing lure that would be best to use for trying to catch fish that are 150 feet below the surface.

+ A light green, orange, or pink lure would be best to use.



3. Use the results of the video to identify colors for a fishing lure that would be bad to use for catching fish that are 150 feet below the surface.

+ Brown, purple, yellow, red



4. As sunlight travels through greater and greater amounts of liquid water, what colors of that light is it absorbing more quickly than others?

+ Purple/violet and red



5. As sunlight travels through greater and greater amounts of liquid water, what colors of that light is it transmitting through it more easily than others?

+ Green, orange, and pink

On Your Own:

6. Using words and/or pictures, show and explain the ways that the matter that the light is passing through is causing changes in the color and brightness that are similar to how the atmosphere causes changes in sunlight that passes through it:

+ Some colors are more readily absorbed or scattered/reflected than others.

+ Some colors are more readily transmitted than others.

+ The more of the matter the light passes through, the less light that is transmitted.

7. Using words and/or pictures, contrast how matter affects the brightness and color of light passing through water differently than it affects light passing through the atmosphere.

+ Different colors are absorbed or scattered, while others are transmitted more readily in liquid water than in the atmosphere.

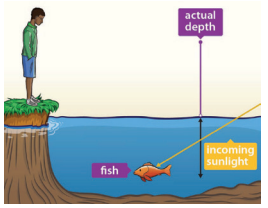
++ For example, red is more easily absorbed in the liquid water but is more easily transmitted in the atmosphere.

+ More light is absorbed more quickly going through water than through the atmosphere. (Or, less light appears to be transmitted through water than through the atmosphere - we see changes in color and brightness sooner in water than we would if the light was passing through as much atmosphere.)

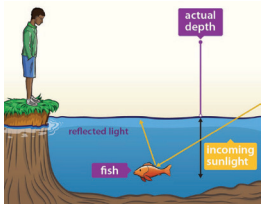
++ Since liquid water has many more particles in it than the atmosphere has (the atmosphere is made mostly of gasses), there are more particles in a given space in the water for light to interact with. So, the light has more opportunities to be scattered and/or be absorbed by particles as it travels through the liquid water than as it travels through the atmosphere, which causes the color to appear to change more quickly in the water.

Part 2: Some fishers do not use lures but use spears to catch fish by looking through the water and then spearing the fish. This is not easy to do because it is hard to see the fish. One issue is that the fish does not appear to be in the spot it actually is under the water! The images below show a model that a group of students developed to explain how light traveling through and out of the water affects the apparent position of fish in the water.

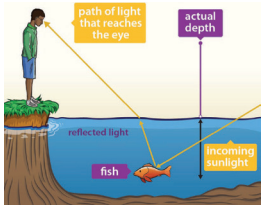
Step 1



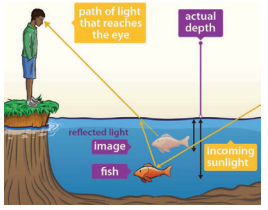
Step 2



Step 3



Step 4



8. What is similar about how light interacts with the matter it passes through in this model compared to the results from your class investigations?

+ Light passing through matter (water or glass) makes objects appear different.

+ The path that light travels changes (refracts) as it travels through different parts of the system.

9. What is different about how light interacts with the matter it passes through in this model compared to the results from your class investigations?

+ For the fish, light goes through the air into the water and back out. For our investigations, light goes through the air through a glass (with or without water in it) and back out into the air.

+ For the glass, light is coming from a flashlight (source), and in this model it is coming from the Sun.

10. Make a prediction: Do you think an object's depth below the surface would affect how much the apparent position of that object shifts for the observer? Explain your reasoning.

+ Accept all answers.

11. Describe an investigation you could design and carry out to test your prediction from question 10.

+ Place an object in a container so that you can see it from an angle. Record its position.

+ Add a small bit of water to cover the object a bit and record its apparent position.

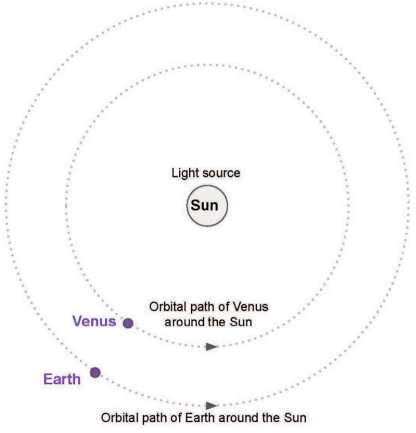
+ Add more water and record its apparent position again. Repeat this step a few times.

Key: Explaining Venus-Related Patterns

Use manipulatives to show where Venus and Earth would need to be located in the system that would help explain each Venus-related pattern below. After doing this, draw and label where Earth, Venus, and the Sun would need to be located in the system to explain what a person on Earth observes related to each phenomena. Use a perspective similar to the one on *Competing Models of the Venus, Earth, and Sun System*, which is drawn looking down on Earth from a location far above the Earth's North Pole.

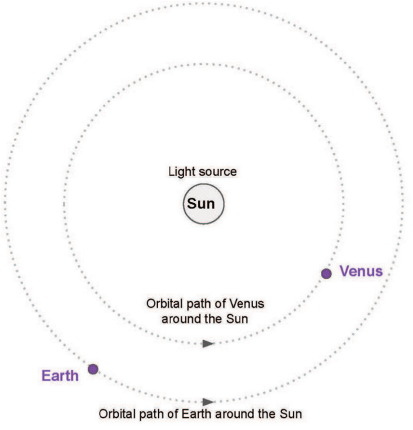
When a transit of Venus can be seen from Earth

Model B: Venus would be located directly in between the Earth and the Sun. For example:



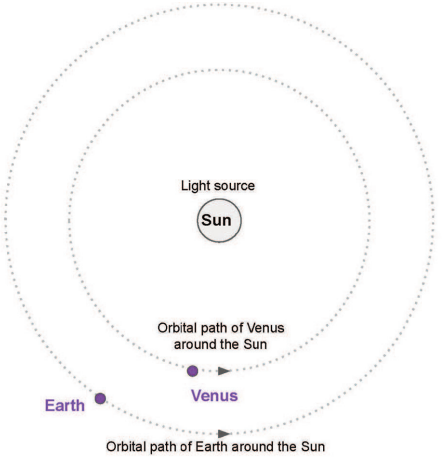
When we see only half of Venus lit up (like a half moon)

Model B: Venus would be located directly to the right or left side of the Sun, relative to the Earth. For example:



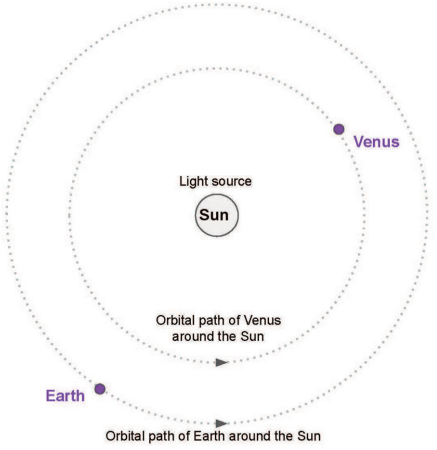
When the size of Venus appears to be bigger than other times it is observed.

Model B: Venus and Earth are closer to one another (a shorter distance between them). For example:

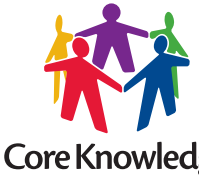


When the size of Venus appears to be smaller than other times it is observed.

Model B: Venus and Earth are further from one another (further distance between them). For example:



Note: these examples all show the Earth in the same position in its orbit. Students may show the Earth in different positions as long as its orbit is exterior to Venus's orbit (as in Model B) and as long as the relative shifts in position of Venus relative to Earth is represented in their model.



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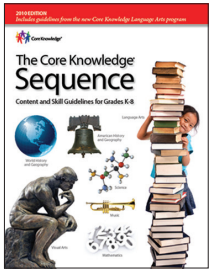
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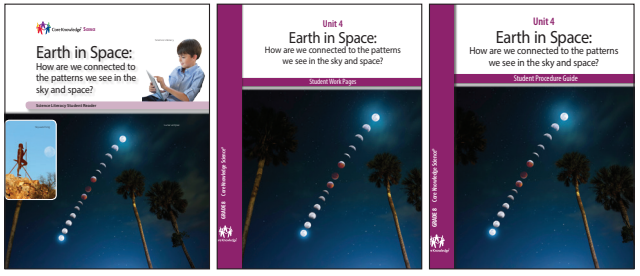
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