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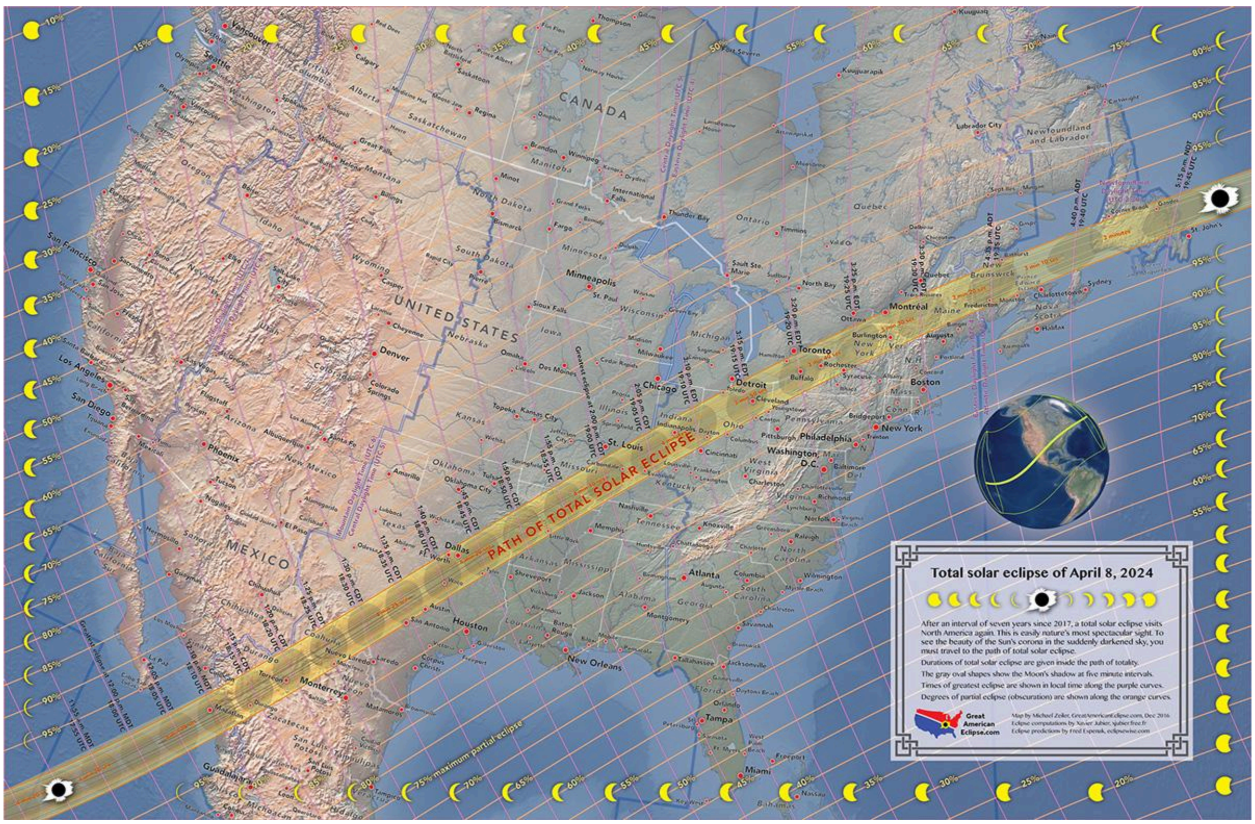
Introduction

A total solar eclipse will occur in the United States on Monday, April 8, 2024, passing across North America with Missouri directly in its path (Fig. 1). A total solar eclipse is where the moon blocks the face of the sun as it passes between the sun and earth. In fact, as the eclipse moves northeast from Dallas, TX through Little Rock, AR and over the eastern part of the state, Poplar Bluff, MO will experience complete totality at 1:56 pm CT. Most of Missouri will be able to experience this celestial phenomenon to some degree. For example, St Louis will see the sky darken, just not see the corona. Even Kansas City in the western part of the state will experience a partial solar eclipse.

Figure 1 - Path of Total Solar Eclipse for April 8, 2024



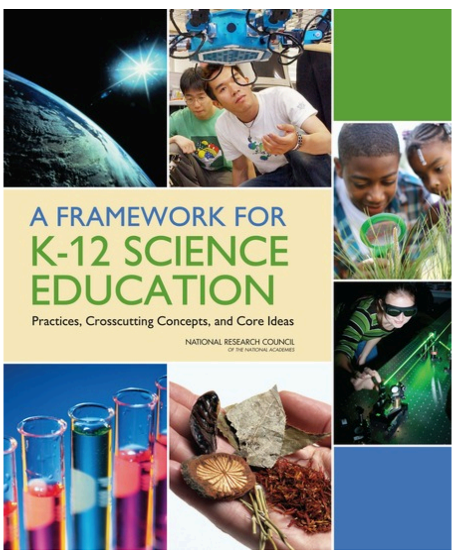
Micahel Zeiler. (2023). Great American Eclipse.com

The following is a resource for all subject-area teachers in Missouri with information about the solar eclipse, lesson ideas and integration, as well as teaching helps with critical thinking and questions. While the target age of this guide is for the middle school learner, adaptations can be easily done for the younger or older student. This guide is in no way exhaustive of the many possibilities to incorporate the solar eclipse into your classroom curriculum, but we are hopeful that it may provide you with a nugget of an idea, an inspiration, or just a reminder that science, language arts, math, history, and fine arts, can all work together to provide engaging and comprehensive learning opportunities for students.

BACKGROUND

Framework

A Framework for K-12 Science Education (2013) encourages the use of phenomena to drive science instruction. Students should engage in explaining phenomena (science) and in solving problems (engineering). Science is defined as the intertwining of the three dimensions—Disciplinary core ideas (DCI), Science and engineering practices (SEP), and Crosscutting concepts (CCC).



National Academies Press. (2013). Nationalacademies.org

The 4 Science Domains with Grade 6-12 (DCI)

AppendixE-ProgressionswithinNGSS-061617.pdf (nextgenscience.org)

- Physical Science
  - 6-12 DCI List
    - PS1: Matter and its Interactions
    - PS2: Motion and Stability: Forces and Interactions
    - PS3: Energy
    - PS4: Waves and their Applications in Technologies for Information Transfer
- Life Science
  - 6-12 DCI List
    - LS1: From Molecules to Organisms: Structures and Processes
    - LS2: Ecosystems: Interactions, Energy, and Dynamics
    - LS3: Heredity: Inheritance and Variation of Traits
    - LS 4: Biological Evolution: Unity and Diversity
- Earth and Space Science
  - 6-12 DCI List
    - ESS1: Earth's Place in the Universe
    - ESS2: Earth's Systems
    - ESS3: Earth and Human Activity
- Engineering, Technology, and Applications of Science.
  - 6-12 DCI List
    - ETS1: Engineering Design

The 8 science and engineering practices (SEP):

Appendix F Science and Engineering Practices in the NGSS - FINAL 060513.pdf (nextgenscience.org)

- Asking questions and defining problems
- Developing and using models
- Planning and carrying out investigation
- Analyzing and interpreting data
- Using math and computational thinking
- Constructing explanations
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating information.

The 7 crosscutting concepts (CCC):

Appendix G - Crosscutting Concepts FINAL edited 4.10.13.pdf (nextgenscience.org)

- Patterns
- Cause and effect
- Scale, proportion, and quantity
- Systems and system models
- Energy and matter
- Structure and function
- Stability and change

Pedagogy

Critical thinking

Browne and Keeley (2007) state that critical thinking focuses on a set of skills and attitudes that enable a listener or reader to apply rational criteria to the reasoning of speakers and writers. Critical thinking begins with observation. Students need time to observe and wonder; to consider possibilities. Before students can evaluate reasoning related to a topic, they first must discover and place importance on questions that unearth reasons and lead to conclusions.

Learning begins with lower-order thinking skills (Bloom, et.al. 1969). Lower does not mean less important. Rather, these skills are the foundation upon which knowledge is built. As students gather information, they analyze and break the information into subject parts. Vocabulary is built, and more questions are generated. Students acquire and remember small bits of information with understanding.

This information is gathered slowly, then connected and used in new ways. Through observing and making connections, students build comprehension and think critically. They evaluate information and make conclusions.

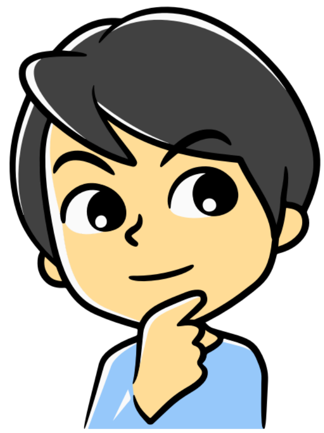
As learning is used in new ways, the level of understanding increases in complexity. The new information is applied to invent, design, or build; to evaluate and make judgments; and to defend or negotiate new ponderings. When students are active participants in the learning, they begin to analyze or synthesize information and compare and contrast the information in new situations.

To facilitate critical thinking in your classroom, consider implementing frequent evaluative questions and active participation. A goal should be to create a learning experience where questions are welcome. Some of the questions come from the teacher and others from students. Not all questions are for a grade or even a check for understanding. Instead, the questioning process drives the learning as students ask questions of each other or use questions to figure out what is next.

Frequent Evaluative Questions

Teachers can assist students in the process by simply asking students, “Why do you think that?” as a follow-up question to a comprehension-based question. Once the reasoning of the student has been identified (hypothesis), other questions can be asked to move students toward an evaluative thought such as the following:

- What words or phrases are unclear or can have different meanings?
- What assumptions are behind the reasons? Are there ideas or beliefs that influence conclusions or explanations?
- What are the facts to support the ideas? Is there proof or information for the reasons, and how valuable is the information?
- How strong or reliable is the evidence that is used to support the reasons?
- Do the comparisons in the argument make sense and are they convincing?
- Do the comparisons or examples in the argument make sense?



- What important information is missing? Are there details missing?
- Are there other possible reasons to explain why certain conclusions were made?
- What other explanations could be made based on the evidence using the same information?

Active Participation

A strength of active participation or an active-learning classroom is that it facilitates personal involvement with the material. Students are more likely to be engaged and willing to discuss and evaluate. Instead of giving students information, design a learning space where they discover and experience it alone and/or with others. Allow time for wonder and curiosity; have hands-on activities for exploration; and encourage tries and failures. As students experience the learning process of gathering information and evaluating it, they develop their critical thinking skills.

Verbal activities

Placing students in small groups encourages active listening and speaking time for all. Movement activities can reinforce vocabulary or content for deeper connection and retention.

Student-led activities produce invested learners. Vary the tasks to make it interesting. Give students choices. Choices are not an anything goes mentality, but are carefully designed options by the teacher that allow for student ownership of the learning.

Turn and Talk Activity

Turn and Talk is an inquiry activator or a “building the field” activity which allows the teacher to gauge student’s understanding of the topic and knowledge of related vocabulary. Using a short prompt or question, students turn to a partner and share their answer or idea while their partner listens, and then, they switch roles. All students have an opportunity to talk and to share. They are engaged with the material and practice listening skills (Stewart, A. & Swanson, E. 2019).

Tap and Talk Activity

Much like the Turn and Talk, the Tap and Talk Activity allows the teacher to gauge a student’s understanding of a topic and related vocabulary. Students are presented with a set of images. With a partner or small group the students take turns tapping/selecting one of the images that they feel they can share something about. (There are no wrong answers.) After all students have shared, the teacher presents a list of terms and the students then select a term that they feel matches the image they selected and explains how they feel they are connected. The teacher then provides a connection between the images and terms as they relate to the coming lesson. (Example)

Collaborative Group Tasks

With the guiding/inquiry questions determined, students begin the investigation process through collaboration and integration. A few ideas for active and collaborative student learning as they investigate.

Science experiments

Students collaborate in small groups to engage in hands-on exploration tasks to investigate their inquiry questions. The students use clear protocols to engage in the experiments and regroup as a whole class to discuss results and interpretations

Research groups

Students work in small, choice-based groups to research their topic and create their projects. Each group member has an assigned role (e.g., time-keeper, note-tracker, encourager, process manager), and the roles change periodically so that each student has an opportunity to experience various roles.

Expert group jigsaw

Students form “expert groups” where each group reads and discusses a different text on the same topic (e.g., different ways that humans impact bat ecosystems). They become experts on the information in that particular text. When they become experts, they need to decide on a few of the most important words to highlight and define. This list of vocabulary can be practiced with the use of repetitive phrases with additional movement such as clapping. The repetitive practice of content with movement increases student engagement and retention.

“Jigsaw groups” are then formed where members of each expert group come together to share their particular area of expertise with members of other expert groups. As students share their expertise, they can present it in different ways such as rhyme, poem, rhythmic clapping or movement. As students present, they are also leading. If the students become “teachers” they are more invested and engaged.

Socratic seminar

Students facilitate a discussion in which they share their opinions on a variety of engaging and open-ended topics, such as debatable solutions to environmental issues. Teachers can model the socratic questioning technique, where each question is answered with another question, to help students dive deeper into the material. Also, learning how to convey their deeper thoughts about a topic can be challenging for students. A teacher assists them to elaborate by asking further questions and the why and how for their reasoning.In their groups, students discuss topics using evidence and facts to support their opinions.

The discussion follows a structured-seminar format in which all students have a role. For example, students in the inner circle discuss the questions, while students in the outer circle take notes on the discussion and “coach” them by critiquing their responses, encouraging them to elaborate, and providing them with needed facts between discussion segments

Collaborative summarizing

Students collaboratively construct, in pairs, a summary statement (15–20 words or fewer) of a short section of an important text (e.g., a few paragraphs on bats, ecosystems, or keystone species) in order to distill the most critical information in the text. The pairs might share their summary with another pair, critique them, and work as a group of four to create a revised one before sharing with the whole class.

Presentation possibilities

Students can share their research and summaries in a variety of ways such as a play, rap, song, poetry reading, or comedy sketch. Students could draw a comic strip or paint a picture. In the jigsaw activity mentioned above, students could make pictures of the information they discovered about bat ecosystems, for example, and then combine the pictures together with the other groups to form a puzzle or large quilt, etc.

The arts methods allow for students to present information and convey their comprehension in different ways than only speaking or writing. This can increase student engagement, collaboration, and retention, and is helpful for differentiation to reach all students in the learning process.

Integrated Academic Reading, Discussion, and Writing

Paired reading tasks

Students read and discuss many different complex science informational texts (first about bats and then about their own keystone species and local ecosystems), using structured note-takers, well-designed prompts, and other supportive methods to promote deeper thinking and extended conversations.

Teacher read-alouds

Teachers model fluent and active reading behaviors by reading aloud a variety of complex texts or text excerpts on the topic, strategically stopping to model and/or have students participate in the following: summarizing what was read, making predictions, responding to text-dependent questions, highlighting effective or interesting language used, or otherwise reflecting on the text.

Science reflection logs

Students write in their science logs daily, responding to open-ended questions from collaborative reading tasks, adding information on their research projects, or taking field notes during field trips or science labs.

Academic vocabulary development

Students learn general academic vocabulary and domain-specific vocabulary, in context. A “young scholars” word wall displays high-leverage general academic words to be used in discussion and writing tasks, and a “science word wall” displays domain-specific words labeling diagrams of bat anatomy, ecosystems, and other important topics. Reinforcement of these words should occur through daily repetitive and rhythmic phrases with movement.

Multimedia and Community Integration

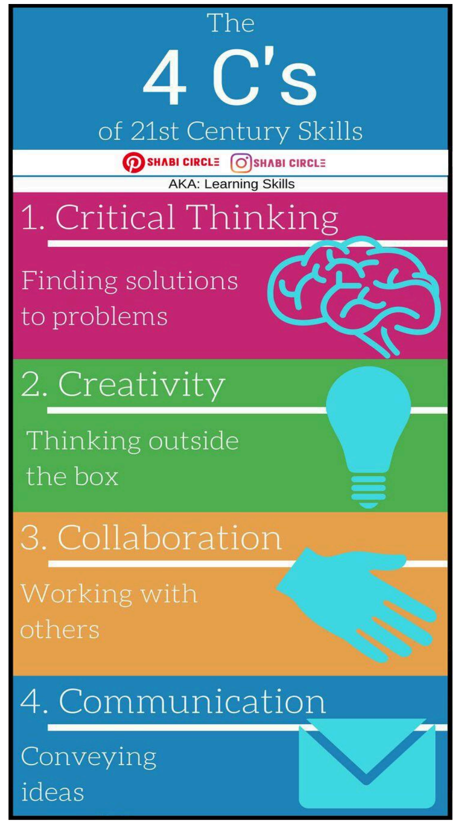
Structured video and podcast discussions provide students the opportunity to view or listen to short, engaging videos and podcasts on the topic. Focus questions and structured note-taking then guide their discussions. During a video viewing, they stop periodically to discuss their notes in pairs or triads and add missing information or revise their notes. They use the notes in their culminating projects.

Ask an expert

Local scientists, activists, or other experts are invited to be interviewed by the class. Local experts who can speak about culturally and community-relevant aspects of the topic are particularly desired. Small groups prepare interview questions in advance and nominate those questions to be asked first. The notes from the interview will be used as evidence for the culminating tasks.

Summary

Critical thinking is one of the four Cs of the 21st century framework for education. This framework includes Communication, Collaboration, Creativity, and Critical Thinking (*Source: Southwest Charlotte STEM Academy (SCSA). https://scstemacademy.org/4-cs-of-21st-century-skills/*). To be successful in today's world, students need to develop autonomy or the ability to work independently. They need excellent problem-solving skills and the ability to innovate and create. Students should also be developing skills to work together collaboratively. In teams, students can build multi-perspective thinking, seeing the world through someone else's eyes. They practice listening skills, gain respect for different opinions or ways of thinking, and develop empathy. By developing the skills of creativity, critical thinking, communication, and collaboration, students will be better prepared for the future.



(Circle, n.d.)

The Science Behind Eclipses (next…)

The Science Behind Eclipses

Disciplinary Core Ideas (DCI)

Earth's Place in the Universe: Universe and Its Stars (ESS1.B)

The pattern of celestial objects in the night sky is a result of the Earth's rotation and its orbit around the Sun, coupled with the vast distances of stars and other celestial bodies.

Earth's Rotation

The Earth rotates on its axis, causing celestial objects (stars, planets, moon) to appear to move across the sky from east to west. This rotation gives rise to the daily rising and setting of celestial bodies. As a result, different constellations become visible at different times during the night.

Earth's Orbit around the Sun

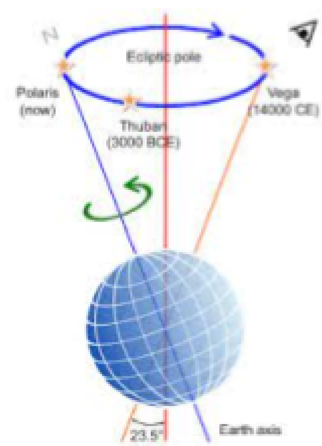
The Earth orbits the Sun, completing one orbit roughly every 365 days. Orbital motion, similar to Earth's rotation, allows for different constellations to enter the viewing field from Earth at different times of the year. Thereby creating an annual cycle of celestial patterns.

Earth orbits at a 23 degree tilt. At different times in the orbit the northern hemisphere of the Earth is tilted toward the Sun (summer) and at other times when the northern hemisphere is tilted away from the Sun, the northern hemisphere has winter.

Constellations and Star Positions

Constellations are patterns of stars that, from our vantage point on Earth, appear grouped together in recognizable shapes. While these stars may be light-years apart in reality, their apparent proximity in our night sky creates the patterns we recognize. Over time, the positions of stars within constellations may shift due to their own motions through the galaxy.

Figure 2.
Diagram showing how the Earth's axis can wobble over thousands of years.



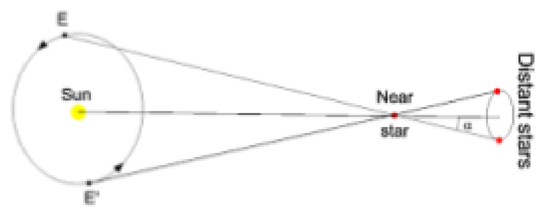
Precession

Earth's axis undergoes a slow, cyclic wobbling motion known as precession. This gradual shift in the orientation of Earth's axis over thousands of years can cause changes in the positions of stars and constellations in the night sky (Fig. 2)

Parallax

As the Earth moves in its orbit, the positions of nearby stars can appear to shift slightly against the more distant stars. This phenomenon, known as parallax, is not noticeable with the naked eye but is a factor when measuring the positions of stars precisely (Fig. 3).

Figure 3.
Diagram of how parallax occurs because the Earth orbits the Sun.



File:Annual parallax.png - Wikimedia Commons

Galactic Rotation

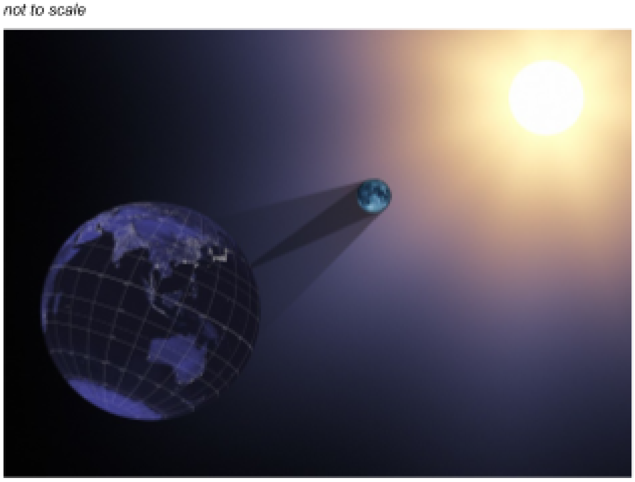
The Milky Way, our galaxy, is a rotating spiral structure. The rotation of the Milky Way contributes to the distribution of stars across the night sky. Depending on our location within the galaxy, different regions of the Milky Way become visible at different times of the year.

Earth's Place in the Universe: **Earth and the Solar System (ESS1.A)**

Sun-Earth-Moon System Overview

Figure 4

Diagram of the Earth-Moon-Sun system from NASA Goddard Space Flight Center. Diagram not to scale



2017 Eclipse: Earth, Moon and Sun | A solar eclipse occurs w… | Flickr

The Sun, Earth, and Moon (Fig. 4) can be considered a system that involves gravitational interactions and movements of the three celestial bodies. The sun, while
containing about 99.86% of the mass of the solar system, is a considered medium-sized star. The Sun is located at the center of our solar system and provides the primary source of energy for

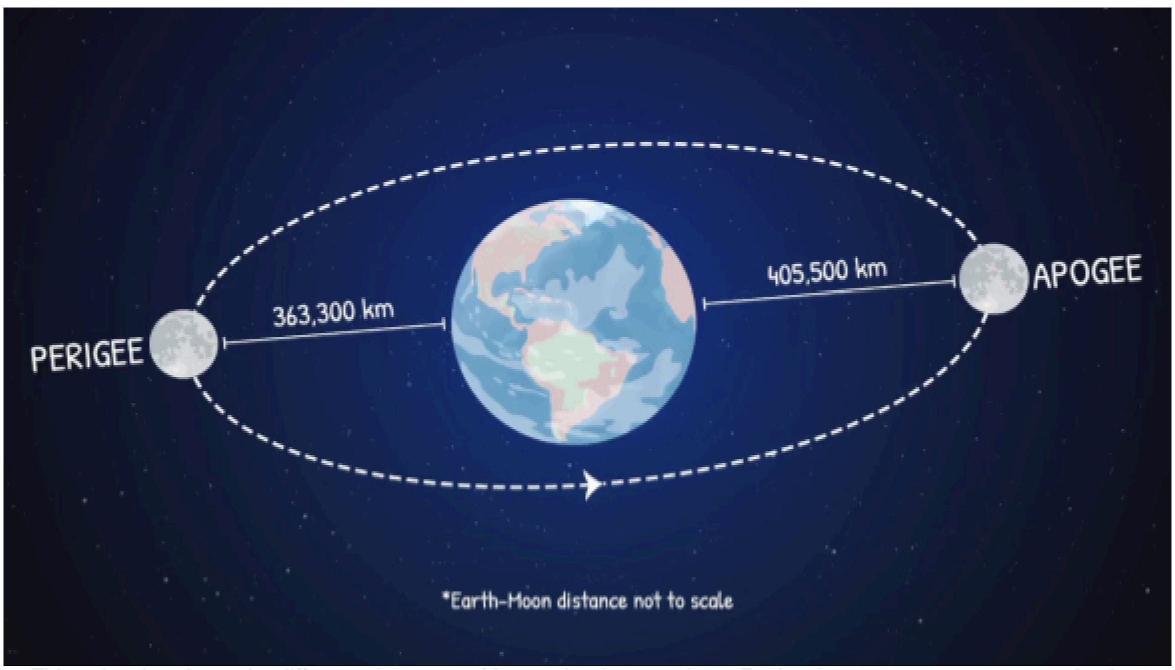
the Earth. With its large mass, the sun also has a central role in the gravitational dynamics of the solar system.

The Earth is the third planet from the Sun and is the only known celestial body to support life. Earth's orbit around the Sun is in the shape of an ellipse (think a slightly flattened circle) and takes 365.25 days to complete.The Earth has a gravitational force of its own which keeps the Moon in orbit around it.

The Moon is Earth's natural satellite. As the Moon orbits the Earth, the same side of the Moon always faces the Earth. This means the Moon orbits at the same rate as it rotates. One orbit takes about 27.3 days to complete. The Moon's orbit is not completely circular (Fig. 5).
The Moon, which is much smaller than the Earth, has its own gravitational force.

Figure 5

Diagram of the Moon's orbit around the Earth. This diagram looks like the orbit is an ellipse, when it is actually more circular. It is the angle at which the orbit is drawn which gives the appearance. Link to animation video:[What Makes a Supermoon Super? (Animation) - YouTube](#) .



This animation shows the difference between a Moon at its closest point to Earth, when supermoons occur, and at its farthest. Distance to apogee and perigee vary by event. Credit: NASA/JPL-Caltech

Lunar Eclipse

Moon Phases

At all times, one-half of the moon's surface is lit by the Sun. Lunar or moon phases (Fig. 6) occur because the moon reveals different illuminated parts to viewers from the Earth as it orbits the Earth. Imagine you are looking at the moon from Earth. The moon doesn't produce its own light; it reflects sunlight. As it orbits our planet, we see from space that different parts of it are lit up by the sun, creating what we call moon phases. In Figure 7, notice that the pattern of moon phases is repeating through the year creating a pattern that can be used to predict future moon phases.

Figure 6

The phases of the Moon as viewed from space and as viewed from Earth.

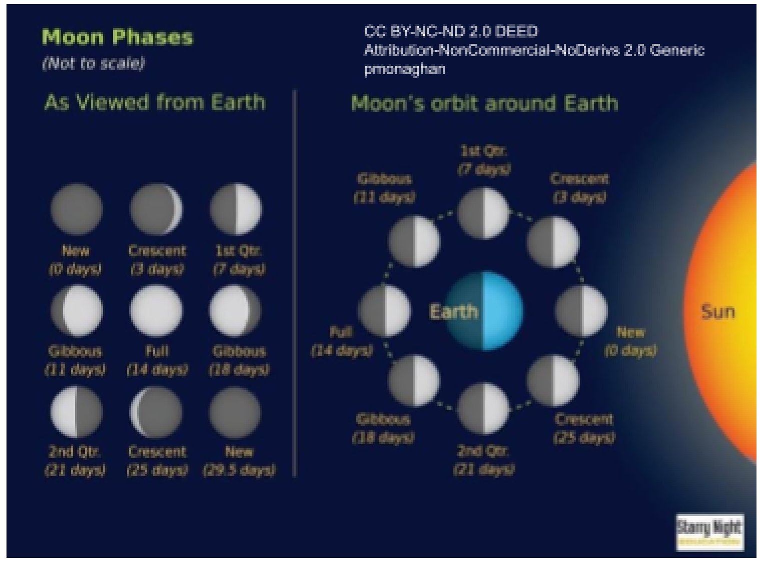
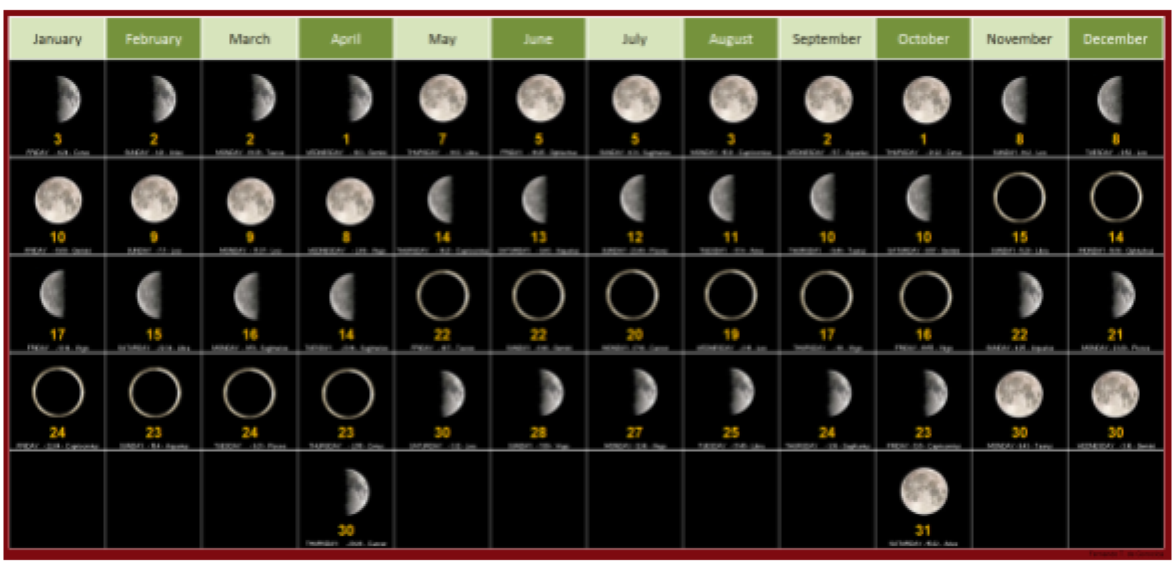


Figure 7

Calendar of the phases of the Moon for 2024



Why is there not a lunar eclipse every month?

A lunar eclipse is where the moon, Earth, and the sun align just right. While the orbits of the moon and the Earth are not circles, for this mental model, we are going to use a circle as the path for both orbits (Fig. 8). Picture the moon's orbit around Earth as a circle, and Earth's orbit around the sun as another tilted circle. When these orbits align and the Moon is in the full moon phase, we witness a lunar eclipse.

Figure 8.

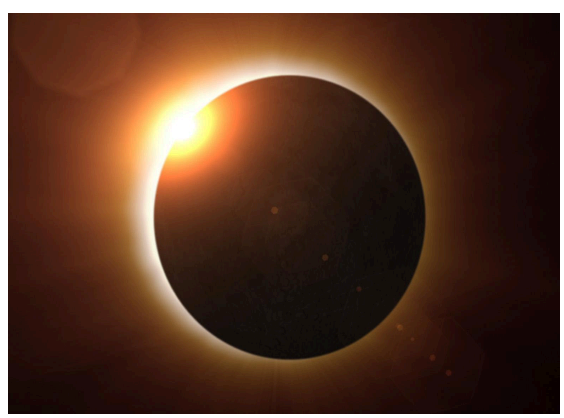
Model for creating lunar and solar eclipses.

960x916-Eclipse-Cups-Hero-P1260666.jpg (960×916) (exploratorium.edu)

The Earth casts a shadow into space considering it blocks light from the sun. The shadow is made of two parts: the umbra, a dark central shadow, and the penumbra, a lighter outer shadow. Think of it like standing in a spotlight—dark in the center and a bit lighter around the edges. As the moon moves through the penumbra, a subtle shading begins, marking the start of the eclipse. Now, when the moon enters the umbra, Earth's atmosphere bends sunlight, turning the moon into a mesmerizing coppery red. When the Earth's umbra completely covers the Moon, it is called a total lunar eclipse. When only a part of the Moon enters the Earth's umbra, it is called a partial lunar eclipse.

Solar Eclipse

A solar eclipse happens when the Moon passes between the Earth and the Sun blocking all or a portion of the Sun's light. Similar to the lunar eclipse, the alignment between the Earth, Sun and Moon must be near perfect for the eclipse to occur. The Moon is in the new moon phase.



Ernie Wright, May 3, 2023.

Another factor in whether an eclipse occurs is the distance between the Earth and Moon along with the elliptical shape of their orbit makes a difference in the apparent size of the Moon and its ability to completely cover the Sun during a solar eclipse. This explains why there are three types of solar eclipses.

1. Total solar eclipse where the Moon completely covers the Sun casting a shadow on a small portion of the Earth’s surface. The region of the Earth where a total eclipse is visible is known as the “path of totality”. Observers within the path experience full obscuration of the Sun by the Moon for a few minutes or a little longer.
2. Partial solar eclipse where the Moon partly covers the Sun and only the penumbral shadow strikes on the Earth’s surface.
3. Annular solar eclipse where the Moon appears smaller (apogee) in the sky than the Sun leaving a ring-like appearance around the edges.

Science and Engineering Practice (SEP)

Developing and Using Models

Teaching students to use scientific modeling involves guiding them through the process of creating, refining, and utilizing models to represent and explain scientific phenomena. Scientific modeling is a powerful tool that helps students develop a deeper understanding of concepts, make predictions, and communicate their ideas effectively. Students do not come to school knowing how to develop scientific models. Similar to all of the science and engineering practices, it needs to be developed over time. Teachers should start by introducing the concept of scientific modeling. Explain what it is and its significance in scientific inquiry. Emphasize that models are simplified representations of real-world phenomena that aid scientists in making predictions and understanding complex systems.

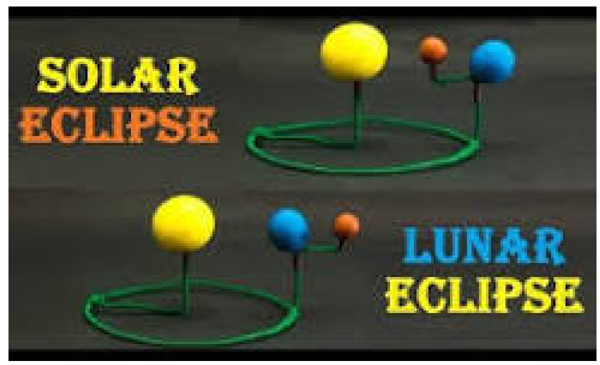
Then, discuss various types of models, including physical, conceptual, and mathematical models. Highlight that the choice of model depends on the nature of the phenomenon being studied.

Provide concrete examples of scientific models used in different fields, such as models of the solar system, cell structures, weather patterns, or ecological systems. Notice that in the few examples listed, the phenomenon in question is too small or too big to be directly observed and manipulated. Relate these examples to how scientists use models to explain, predict, and understand complex phenomena. Communicate that modeling is an iterative process. Models are refined and improved by scientists as new data becomes available or as understanding deepens. Encourage students to see modeling as a dynamic tool that evolves over time.

Implementing models in the classroom

One method is to begin with guided modeling exercises where students work on a specific scientific concept as a class. This could involve constructing a model on the whiteboard, creating a physical model, or using a simulation tool. Provide support and guidance as students work through the process. Foster a classroom environment where questions and discussions about the models are encouraged. This helps students refine their understanding and consider alternative perspectives.

Align modeling activities with the Science and Engineering Practices outlined in the Next Generation Science Standards (2013). These practices include asking questions, developing and using models, analyzing and interpreting data, and constructing explanations. Integrate technology tools and simulations that allow students to create dynamic and interactive models.



Virtual labs, computer simulations, and modeling software can enhance the learning experience and provide opportunities for experimentation. Develop assessment tools that evaluate students' ability to create and use models effectively. Encourage self-reflection on the modeling process, emphasizing the importance of learning from both successes and challenges.

Gradually transition to more independent modeling projects. This could involve students selecting a topic of interest, conducting research, and constructing a model to represent and explain a specific phenomenon.

Obtaining, Evaluating, and Communicating Information

NGSS emphasizes the importance of the science and engineering practice of obtaining, evaluating, and communicating information (2013) . This practice is integral to the scientific process and is crucial for developing scientifically literate individuals.

Obtaining information involves gathering relevant data from a variety of sources, including observations, investigations, and research. This practice encourages students to develop skills in data collection, whether through hands-on experiments, fieldwork, or analyzing existing scientific literature. The ability to obtain accurate and reliable information is foundational to scientific inquiry.

The next step is evaluating the information collected. This involves assessing the quality and reliability of data, considering the sources of information, and critically analyzing the evidence. Students learn to distinguish between credible and unreliable sources, identify biases, and assess the validity of scientific claims. This critical evaluation is essential for drawing accurate conclusions and making informed decisions.

Communicating information is a key aspect of the scientific process. Students must learn to articulate their findings, conclusions, and the evidence supporting their claims. This practice involves effective communication through various mediums, including written reports, oral presentations, and visual representations. Clear communication ensures that scientific knowledge can be shared, understood, and built upon by the broader scientific community and the public.

Why is Obtaining, Evaluating, and Communicating Information Important?

Scientific Inquiry

It aligns with the fundamental process of scientific inquiry, where information is collected, analyzed, and shared to advance understanding.

Critical Thinking

It promotes critical thinking skills as students learn to assess the quality and reliability of information, fostering a skeptical and inquisitive mindset.

Real-World Application

These skills are applicable not only in the scientific field but also in everyday life. Individuals need to navigate a wealth of information critically and communicate effectively in various contexts.

Preparation for STEM Careers

For those pursuing careers in science, technology, engineering, and mathematics (STEM), the ability to obtain, evaluate, and communicate information is a foundational skill necessary for success in research and innovation.

The NGSS integrates this practice throughout the standards, emphasizing its importance across all scientific disciplines. Whether students are conducting experiments, analyzing data, or presenting their findings, the practice of obtaining, evaluating, and communicating information is woven into the fabric of scientific learning.

Crosscutting Concepts (CCC)

Patterns (CCC)

Patterns play a crucial role in science education for students and are fundamental to developing scientific literacy and understanding (NGSS, 2013). A pattern is a regular and repeated arrangement of elements or features. In various contexts, a pattern may refer to a discernible and predictable sequence, design, or set of characteristics that repeats or recurs in a systematic way. Patterns can be observed in a wide range of phenomena, including mathematics, art, nature, language, and many other fields.

In mathematics, a pattern might involve a series of numbers or shapes that follow a specific rule or sequence. In art, a pattern could be a repetitive design or motif. In nature, patterns are often evident in the arrangement of leaves on a tree, the markings on an animal's fur, or the regular structure of a crystal.

Patterns can be simple or complex, and their recognition and analysis play a significant role in fields such as science, mathematics, computer science, and design. Identifying patterns allows for the prediction of future occurrences, problem-solving, and a deeper understanding of the underlying structure of various systems and phenomena.

Why are patterns important in science?

Observation and Recognition

Patterns provide a framework for students to observe and recognize regularities in the natural world. Recognizing patterns helps students make sense of complex information and identify recurring relationships between variables.

Predictions and Inferences

Understanding patterns allows students to make predictions and draw inferences. By recognizing patterns, students can anticipate outcomes and make informed hypotheses about how systems work, fostering a deeper understanding of cause and effect in scientific phenomena.

Problem Solving

Patterns aid in problem-solving by enabling students to identify similarities and differences in data. This skill is crucial for analyzing information, drawing conclusions, and devising strategies to solve scientific problems.

Critical Thinking

Exploring patterns encourages critical thinking skills. Students learn to question, analyze, and interpret. information, fostering a mindset that is essential for scientific inquiry and exploration.

Mathematics Connection

Patterns in science often involve mathematical relationships. Studying patterns helps students apply and reinforce their math skills in a real-world context, making connections between mathematical concepts and scientific observations.

Organizing Information

Patterns help students organize information systematically. Whether it's classifying organisms, understanding periodic trends in the periodic table, or interpreting weather data, recognizing patterns aids in structuring information logically.

Technology and Data Analysis

In today's digital age, students often encounter large sets of data. Understanding patterns is crucial for effective data analysis, helping students navigate through information, identify trends, and use technology tools to visualize and interpret data.

Cross-Curricular Learning

Patterns are not limited to one specific field of science. Recognizing patterns fosters cross-curricular connections, allowing students to apply their understanding of patterns across different scientific disciplines and even in other subjects.

A visual example of patterns are when vibrations of sound create patterns depending on the frequency. Figure 9 depicts the note D played with a bow on the side of a metal plate as sand was tossed across it.(Chau tu, 2016)

Figure 9 Vibrations of G. Credit: Louviere + Vanessa

Scientific Inquiry

Science is an ongoing process of asking questions and seeking answers. Recognizing patterns is a key aspect of scientific inquiry, as students learn to formulate hypotheses, design experiments, and draw conclusions based on observed patterns in data.

Real-World Relevance

Many natural phenomena exhibit patterns, and understanding these patterns enhances students' appreciation of the world around them. From seasons and weather patterns to biological cycles and geological processes, patterns are integral to explaining and predicting real-world phenomena.

Systems and Systems Models (CCC)

A system is a set of interconnected and interdependent components or parts that work together to achieve a common purpose or goal. In the context of various disciplines, including science, engineering, biology, and social sciences (NGSS, 2013). The term "system" is used to describe a complex whole made up of interacting elements.
Key characteristics of a system include the following:

Interconnected Components

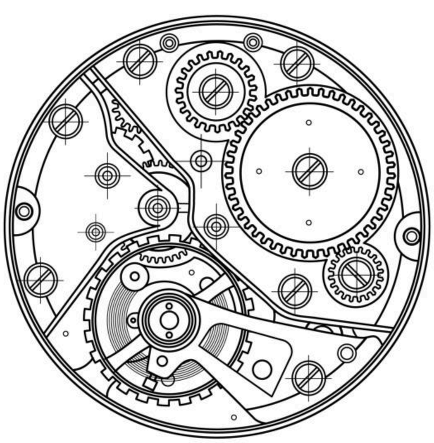
A system is composed of multiple components or parts that are connected and interact with each other. These interactions can involve the exchange of energy, matter, or information.

Interdependence

The components within a system depend on each other in some way. Changes in one part of the system can affect other parts, and the system as a whole may exhibit emergent properties that arise from the interactions of its components.

Purpose or Goal

Systems are organized to achieve a specific purpose or goal. This purpose may involve the efficient functioning of the system, the accomplishment of a task, or the maintenance of a particular state or condition.



Boundaries

Systems have boundaries that distinguish them from their external environment. The boundary defines what is considered part of the system and what is external to it. The exchange of matter, energy, or information across the boundary is a defining characteristic.

Inputs and Outputs

Systems typically receive inputs from their environment, process these inputs internally, and produce outputs. The inputs and outputs can be in the form of matter, energy, or information.

Feedback Mechanisms

Systems often incorporate feedback mechanisms, where information about the system's output is used to regulate or modify its behavior. Feedback can be positive, amplifying a response, or negative, stabilizing the system.

Examples of systems are abundant in nature and human-made environments. Common examples include ecosystems (composed of living organisms and their environment), the human body (composed of organs and organ systems), a car engine (composed of various mechanical and electrical components), and social systems (such as economic or political systems).

Why are systems important to science?

Understanding systems is a fundamental concept in various scientific disciplines, as it allows for the analysis of complex interactions, the prediction of system behavior, and the identification of patterns and relationships within the components of the system. Understanding systems helps students make sense of the natural world and the interconnectedness of various phenomena. Here are some key reasons why systems are important in science:

Interconnectedness of Components

Systems thinking emphasizes the idea that everything is interconnected. It helps students see how different components or parts within a system interact with each other. This perspective is essential for understanding complex natural phenomena.

Holistic Understanding

Systems thinking encourages a holistic approach to studying natural processes. Instead of focusing solely on individual elements, students learn to consider the entire system and how its parts work together. This approach allows for a more comprehensive and nuanced understanding of scientific concepts.

Causation and Relationships

By studying systems, students can explore cause-and-effect relationships within natural processes. They can investigate how changes in one part of a system affect other components. This helps develop critical thinking skills and the ability to identify patterns and relationships in scientific data.

Real-world Applications

Many real-world phenomena can be understood and analyzed as systems. This includes ecosystems, the human body, weather systems, and more. Teaching systems in 8th-grade science provides students with a framework to analyze and understand the complexity of the world around them.

Problem-Solving Skills

Systems thinking encourages students to approach problem-solving in a systematic way. They learn to break down complex issues into manageable components and analyze the interactions among those components. This skill is valuable not only in science but also in various other disciplines and real-life situations.

Cross-Disciplinary Learning

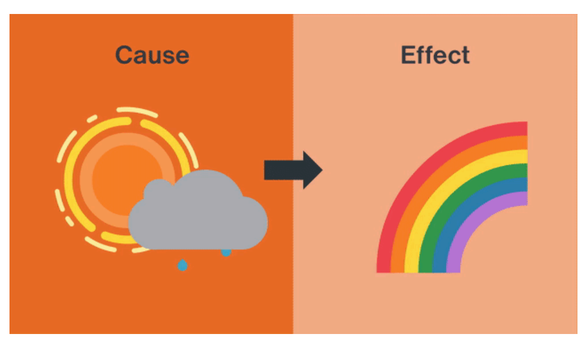
Systems thinking is applicable across different scientific disciplines. Whether studying biology, chemistry, physics, or environmental science, understanding systems provides a common framework that can be applied in diverse contexts. This cross-disciplinary approach fosters a more integrated and interconnected view of science.

Preparation for Advanced Concepts

As students progress in their science education, they encounter more complex concepts and systems. Introducing the idea of systems in 8th grade sets the foundation for understanding more advanced scientific principles in high school and beyond.

Cause and Effect (CCC)

The concept of cause and effect refers to the relationship between events or variables where one event, the cause, brings about another event, the effect. In other words, it is the understanding that certain conditions or actions lead to specific outcomes. The cause is what makes something happen, and the effect is what happens as a result.



Ravenscroft, T.M. (2020). *Skills Builder Handbook for Educator*

This concept is fundamental to various disciplines, including science, philosophy, and everyday reasoning. In scientific contexts, understanding cause and effect is essential for explaining natural phenomena, formulating hypotheses, and conducting experiments. In daily life, people often use cause-and-effect reasoning to make predictions, solve problems, and understand the consequences of their actions.For example: In this simple cause-and-effect relationship, the cause (excessive rain) leads to the effect (flooding). Understanding such relationships helps individuals make sense of the world around them and make informed decisions based on the likely outcomes of different actions or situations.

Why is cause and effect important?

The crosscutting concept of cause and effect is crucial for students to learn because it forms the basis for understanding the interconnectedness of natural phenomena and events in the world. This concept encourages students to explore the relationships between variables, events, and processes and to recognize that actions have consequences. Here are several reasons why teaching cause and effect is important:

Scientific Inquiry

Understanding cause and effect is fundamental to the scientific method. Scientists formulate hypotheses based on cause-and-effect relationships and design experiments to test these hypotheses. By grasping this concept, students develop essential skills in scientific inquiry.

Problem Solving

Cause-and-effect thinking is essential for effective problem-solving. Students who can identify the causes and effects of a situation are better equipped to analyze and solve problems, both in science and in everyday life

Predictive Skills

Recognizing cause-and-effect relationships enables students to make predictions. When they understand the factors influencing an outcome, they can anticipate the results of changes or interventions. This predictive skill is crucial in both scientific investigations and real-world decision-making.

Critical Thinking

Cause-and-effect analysis promotes critical thinking. Students learn to evaluate evidence, consider multiple factors, and discern the relationships between variables. This skill is valuable not only in science but also in other academic disciplines and in making informed decisions as citizens.

Systems Thinking

Cause and effect are integral to understanding systems. Systems thinking involves recognizing how various components interact within a system. By understanding the cause-and-effect relationships within systems, students gain insights into complex ecological, biological, and physical systems.

Interdisciplinary Connections

Cause and effect cut across different scientific disciplines and connect to other areas of study. Learning about cause and effect helps students see the interdisciplinary nature of science and its connections to mathematics, technology, and engineering.

Real-World Application

Cause-and-effect understanding is applicable in various real-world scenarios. Whether considering environmental issues, societal challenges, or personal choices, recognizing cause and effect helps students navigate and understand the complexities of the world around them.

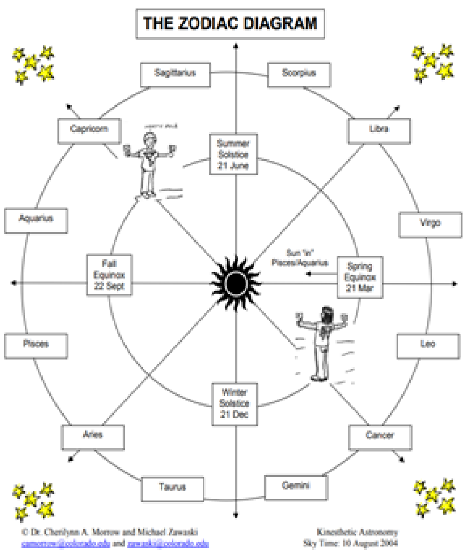
Review Lesson

Begin the lesson with a brief review of what students learned in the 5th grade regarding the patterns of stars in the night sky and how they change over the course of a year.

Kinesthetic Astronomy

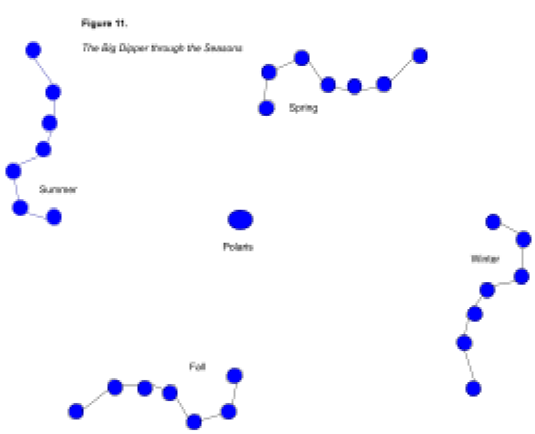
One place for a more in-depth review is Kinesthetic Astronomy. Figure 10 shows a diagram and questions about the patterns of stars from *Kinesthetic Astronomy (*10 August 2004*)*. An answer guide for teachers follows.

Figure 10. Zodiac Diagram



1. If the month is January, what zodiac constellations are present in the night sky for the northern hemisphere?
2. Why would constellations such as Sagittarius or Capricorn be difficult to see during January in the northern hemisphere?
3. What is the repeating pattern of zodiac constellations during the year? Why does the pattern repeat?

Figure 11. The Big Dipper



4. Why are some constellations, such as the Big Dipper, easily seen from the northern hemisphere all year, but only change in orientation (Figure 11)?

Journal of observations

While working through this review lesson, make observations of the moon at night (or day, depending on the phase) as observations in a journal.

Answer guide for the teacher

- If the month is January, what zodiac constellations are present in the night sky for the northern hemisphere?

To answer this question, students will need to know how to read the provided diagram. First, students need to observe that the person in the diagram is standing during the month of January. Then, students will need to orient themselves. If they are facing the Sun, it is daytime. If they are facing outward, it is nighttime, and the constellations are visible during the night.

- Why would constellations such as Sagittarius or Capricorn be difficult to see during January in the northern hemisphere?

This question asks for a reason for why Sagittarius and Capricorn are difficult to see and may tip students to go to their answer for the first question. Students need to respond with a bit of their reasoning from above. The Sun is too bright compared to the stars in the sky during the day and obscures the viewing of those constellations.

- What is the repeating pattern of zodiac constellations during the year? Why does the pattern repeat?

This is an example of looking for comprehension, then asking for reasoning. Using the diagram, students can put the zodiac constellations in order according to the months of the year. To explain their reasoning, students should mention that the Earth follows an orbital path that takes approximately 365 days to complete. The Earth follows a similar orbital path every year. The constellations are made of stars that are essentially in fixed positions that are many light years apart (stars are actually moving, but the extreme distance makes their movement barely noticeable). Between both things, the pattern of constellations repeats.

- Why are some constellations, such as the Big Dipper, easily seen from the northern hemisphere all year, but only change in orientation?

This question also asks about the reason behind a noticeable pattern that is presented in the diagram. Students should explain that the location of the Big Dipper is near the North Star. Currently, our North Pole points toward the North Star. The proximity of the Big Dipper, and the fact that we orbit around the Sun, mean that the orientation of the dipper changes with the location of the Earth and Sun. Admittedly, this concept is more involved and might not have been covered as part of the 5th grade curriculum.

Opportunities for Student Responses

One idea as part of reviewing the patterns of stars with students would be to print the cards with the constellations and hang them around the classroom. These visuals can aid students as you use the diagram for a quick check of understanding. Students can provide written responses to the questions or the questions can be used for class discussion.

Other possible ways to check for understanding and review can follow the round of questioning as seen in Table 1. This work from Page Keely is a Formative Assessment Classroom Technique known as Vote - Discuss - Revote (2016).

Table 1

Round 1:	**Students answer the questions as individuals.**
Round 2:	**Students find a partner to discuss their answers. Their partner could have a similar response or a different response. The purpose of the discussion is to either decide on evidence and reasons to support their answer or to come to agreement on a best answer.**
Round 3:	**Group students into larger heterogeneous groups. The purpose of the larger groups is to come to a consensus on the best answer. If students do not have agreement across the class by the end of Round 3, they are in need of instruction.**
Round 4:	**This is where you might consider using the complete *Kinesthetic Astronomy* lesson or find some readings.**

Round of Questioning

Description of the 4 rounds of class discussion for students to find the best answer to the review questions using Vote - Discuss - Revote technique (Keely, 2016).

Celestial Puzzle

To further develop learning, students could read *The Celestial Puzzle: Unveiling the Seasonal Symphony of Stars (German, 2023)*. This reading (Figure 12) can build upon the classroom discussion. Readings that follow experiences in the classroom can help students build a better conceptual framework.

The Big Dipper in Autumn

Media from the International Astronomical Union with known IDsCC-BY-4.0International Astronomical Union Images Spacemedia files uploaded by OptimusPrimeBot under the identifier ann22042c-autumn

Figure 12. The Celestial Puzzle: Unveiling the Seasonal Symphony of Stars (German, 2023)

Ever wonder why specific constellations grace our night sky only during certain months?

In the night sky, observers follow the celestial spectacle that changes as the Earth rotates and moves through its annual journey around the Sun. As the earth completes its axial rotations, different portions of the sky become visible, revealing a display of stars.

The changing seasons also play a key role. During the winter months, the Northern Hemisphere tilts away from the Sun exposing a distinct set of constellations. One such winter constellation is Orion, recognizable by its belt of three bright stars. From December to March, Orion is visible to observers on Earth.

As Earth transitions to spring, there are new constellations. Leo, with its distinctive celestial mane, graces the night sky from late winter to early summer. Ancient mythology tried to explain why Leo was seen in the night sky. An example from Egyptian mythology was that the Nile River flooded when Leo appeared in the sky. The flooding of the Nile River was considered to be a good omen as it was a source of irrigation for the land.

As summer unfolds and the days lengthen, additional constellations become visible in the night sky while previously visible constellations move out of the night sky viewing (until next year). Hercules, the mythological strongman, flexes across the heavens, while the Summer Triangle, formed by the stars Vega, Deneb, and Altair, appears in the summer night sky. These constellations illuminate our view from late spring to early autumn.

As autumn arrives, the Great Square of Pegasus, resembling a winged horse, becomes viewable in the night sky. Its stars create a square pattern, inviting stargazers to connect the dots.

The key to this changing celestial sky lies in Earth's axial tilt and its orbit around the Sun. The night sky, then, becomes similar to a dynamic canvas, showcasing seasonal constellations that appear and disappear with each Earthly orbit.

Lesson 1 Lunar Eclipse (coming up next…)

Lesson 1 Lunar Eclipse

In this lesson, students will explore the following concepts that contribute to the learning about the eclipse:

Part 1) the patterns of the moon phases

Part 2) the travel of light and shadows

Part 3) the orbiting of the sun, earth, and moon.

A Framework for K-12 Science Education (2012) encouraged the use of phenomena to drive science instruction. Students should engage in explaining phenomena (science) or solving problems (engineering). It also defined science to be taught as the intertwining of the three dimensions: disciplinary core ideas (DCI), science and engineering practices (SEP), and crosscutting concepts (CCC). One of the SEPs, students should obtain, evaluate, and communicate information, will inform the lesson format used here, Gather-Reason-Communicate (GRC). GRC turns practice into a structure to design a science lesson (Moulding, 2024).

In the Gather phase of the lesson, students search for the information they need to figure out the phenomenon of study (in this case, eclipses). Students typically develop questions, obtain information, plan and carry out investigations, use mathematical and computational thinking, and/or use models to gather and organize data and information. Activities will be implemented to assist students in gathering and understanding the information such as an observational journal, use of the question formulation technique, drawing diagrams, and making models (Moulding, 2024).

Gather

Part 1 - Patterns of the Moon Phases

Journal and Observations

Students should begin by keeping a journal of observations of the moon at night (or day, depending on the phase). It would be helpful to have a full month of observations, but it is not necessary. These can be supplemented with data found on the Internet. Ask students to look for patterns in their journal of observations. Once students have a pattern for their observational data, provide students with annual calendars (Figure 15) that show the moon phases to check to see if their pattern holds up to more information or data.

Question Formulation Technique

To assist students in developing questions, the Question Formulation Technique (Right Question Institute, 2024) is outlined below. Students are asked to produce as many questions as possible that follow these rules:

- Ask as many questions as you can of the resource (the calendar of moon phases).
- Do not stop to discuss, judge, or answer questions.
- Record the questions exactly as they were stated.
- Change any statements to questions.
- Number your questions.

Once they have exhausted all of the questions they can think of, they begin the process of evaluation and categorize their questions, The goal is to improve the questions by categorizing them as close-ended, where the questions are answered with “yes” or as open-ended, where the questions are answered with “no” and require a longer explanation. If it is a closed question, students should rewrite the question as an open question.

As the teacher, make sure to keep some questions in your back pocket that can help students come up with the type of questions that you are looking for such as the following:

- How do the phases of the moon change over time?
- How can you represent that change mathematically?
- How can you use the pattern to predict the phases of the moon for 2025?
- What might be causing this?

Then, following the labeling of questions, some strategy comes into play as students prioritize the questions and create an action plan on how to share the questions. Students can prioritize their question lists by level of importance to them. Share the lists in class and look for areas of overlap. Notice that one of the questions provided as a “back pocket question” has students looking for a pattern in the moon phases. Prioritize that question at the top for students to look through their moon observation data.

Model of First Thoughts

Using the SEP practice of developing and using models, encourages students to put their thinking on paper. It may feel out of place considering that students have not had instruction in moon phases, however it serves several purposes in student learning.

First, it provides a basis for students to put their first thoughts on paper. Students are often hesitant to do this, because of fear of being incorrect. This is where I use the phrase, first thoughts, with students. First thoughts are our starting point. As a class, we will come back to our first thoughts after learning and make improvements to the model. A possible example (Van Zee & Gire, 2020) is figure 14.

Second, when students create a model with little prior instruction, it helps them to get their thinking on paper and serves as a formative check. This can show students what they need to learn, and help you, as a teacher, know where they are at in understanding concepts. That insight should be used to guide future lessons to emphasize key points. For example, if you notice several students are holding an alternative conception of why moon phases occur, you may structure future activities to directly confront those alternative conceptions in hopes of students realizing their thinking needs to change.

Activity for Model of First Thoughts

DIRECTIONS: Students will draw a model that explains the cause(s) of the moon phases and the patterns that are seen from Earth using the moon phase model (Monaghan, 2011) in figure 15.

1) Students put their first thoughts down regarding the model of the moon phases. (It is okay if students do not have the proper concept at this point.
2) A list of possible alternative conceptions of the Moon or moon phases:
    - The Moon can only be seen at night

- The Moon makes its own light, instead of reflecting sunlight.
- The Moon’s phases are caused by the Earth’s shadow.
- The Moon’s phases are caused by clouds.
- The Moon’s phases are caused by Earth’s rotation on its axis.
- The Moon’s phases are caused by the Moon’s rotation on its axis.
- The Moon takes one day to orbit the Earth.
- The Moon orbits the Sun instead of the Earth.

Part 2 - Shadows

How can a mouse’s shadow be as big as an elephant’s shadow? Another piece to understanding the eclipse is in exploring shadows. In first grade, students develop an understanding of what happens when objects are put in the path of light. In fourth grade, students build a model that explains how light reflects off an object and allows them to see it. The idea that light travels in a straight line may or may not have been learned yet. Thinking about how light travels is an abstract concept for students, so a review is probably necessary.

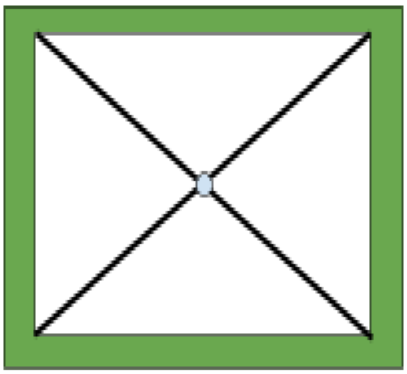
This lesson is an important piece considering that the Moon does not produce its own light. Instead, it reflects the light from the Sun. Knowing how light travels and creates shadows is the basis for understanding what is causing the moon to appear differently from Earth as well as eclipses. This also begins a supporting level of conceptual development for students. Some students may think that Moon phases are created by the shadow of the Earth on the Moon. The initial or first thoughts model activity as well as the question development activity should have brought the need to understand how light travels as a piece of the puzzle students are working on. By making certain students understand how light travels first, the ideas of the phases of the Moon might make more sense to students.

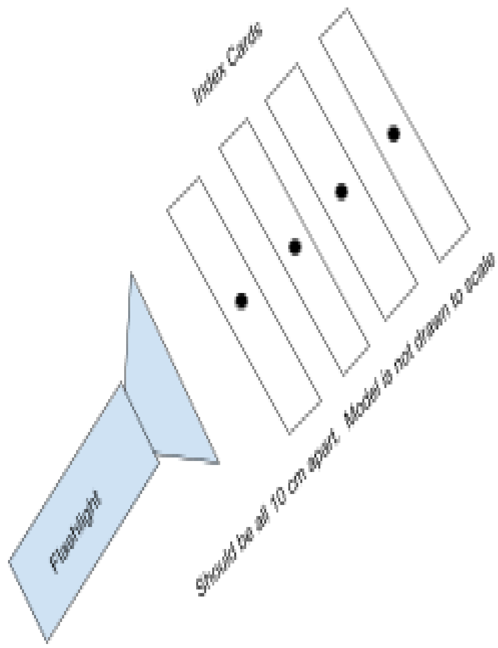
The next part of this lesson is designed to instruct or review this information utilizing two activities that demonstrate how light travels and how shadows change size. A complete guide can be found in the article, *How to Prove that light travels in a straight path*, (n.d.) https://www.wikihow.com/Prove-That-Light-Travels-in-a-Straight-Path

Activity 1 - How does light travel?

The moon does not produce its own light. Instead, it reflects the light from the Sun.

1. On four index cards, draw lines from corner to corner to make an X. Make a hole at the center fo the X with a hole punch





2. Stand the index cards up on a table using small lumps of clay or clothespins. Place the cards about 10 cm apart and line the holes in a straight line.

3. Put a flashlight about 10 cm in front of the first card. Turn on the flashlight (if needed, place the flashlight on a book so the light can shine through the holes).

Example of student model of moon phases (Van Zee & Gire, 2020).

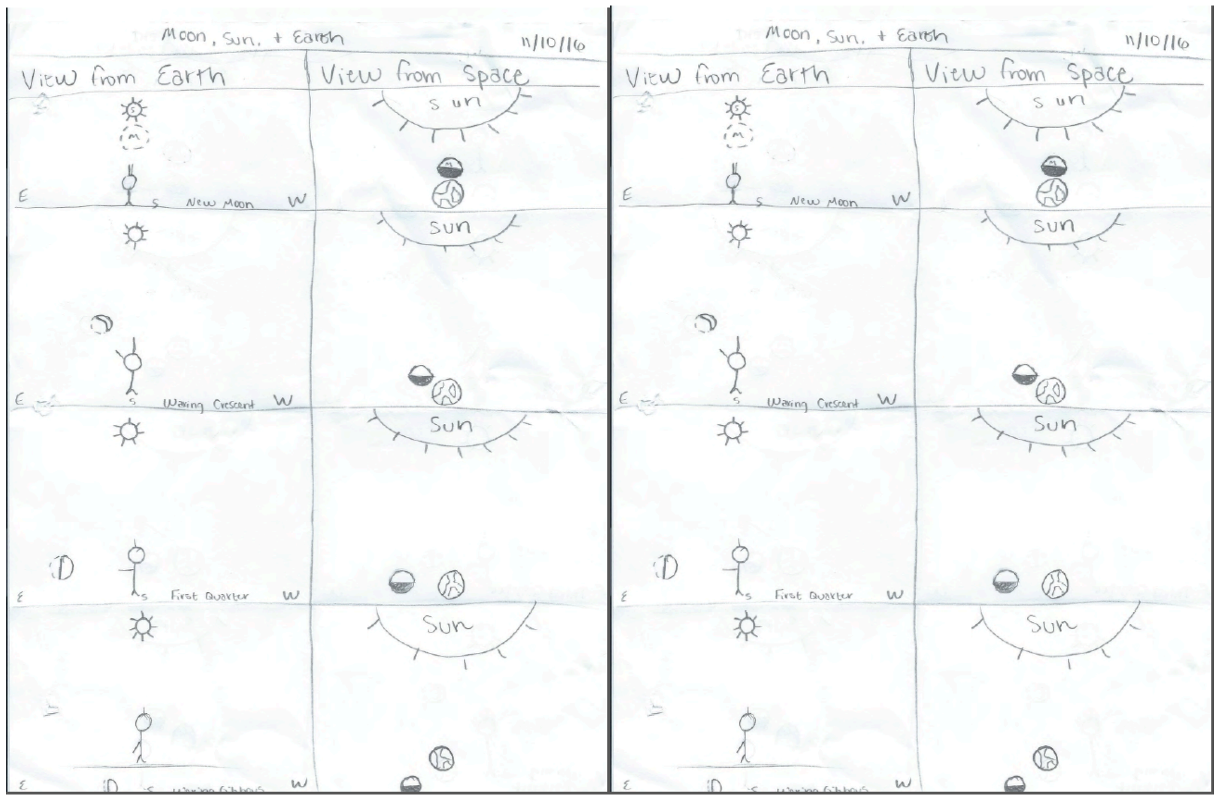
Figure 14

Moon Phases

Gotta' have list

- ☐ Moon
- ☐ Earth
- ☐ Sun
- ☐ ---- or ----> for light rays
- ☐ New Moon phase
- ☐ Full Moon phase
- ☐ First Quarter phase
- ☐ Third Quarter phase

Example

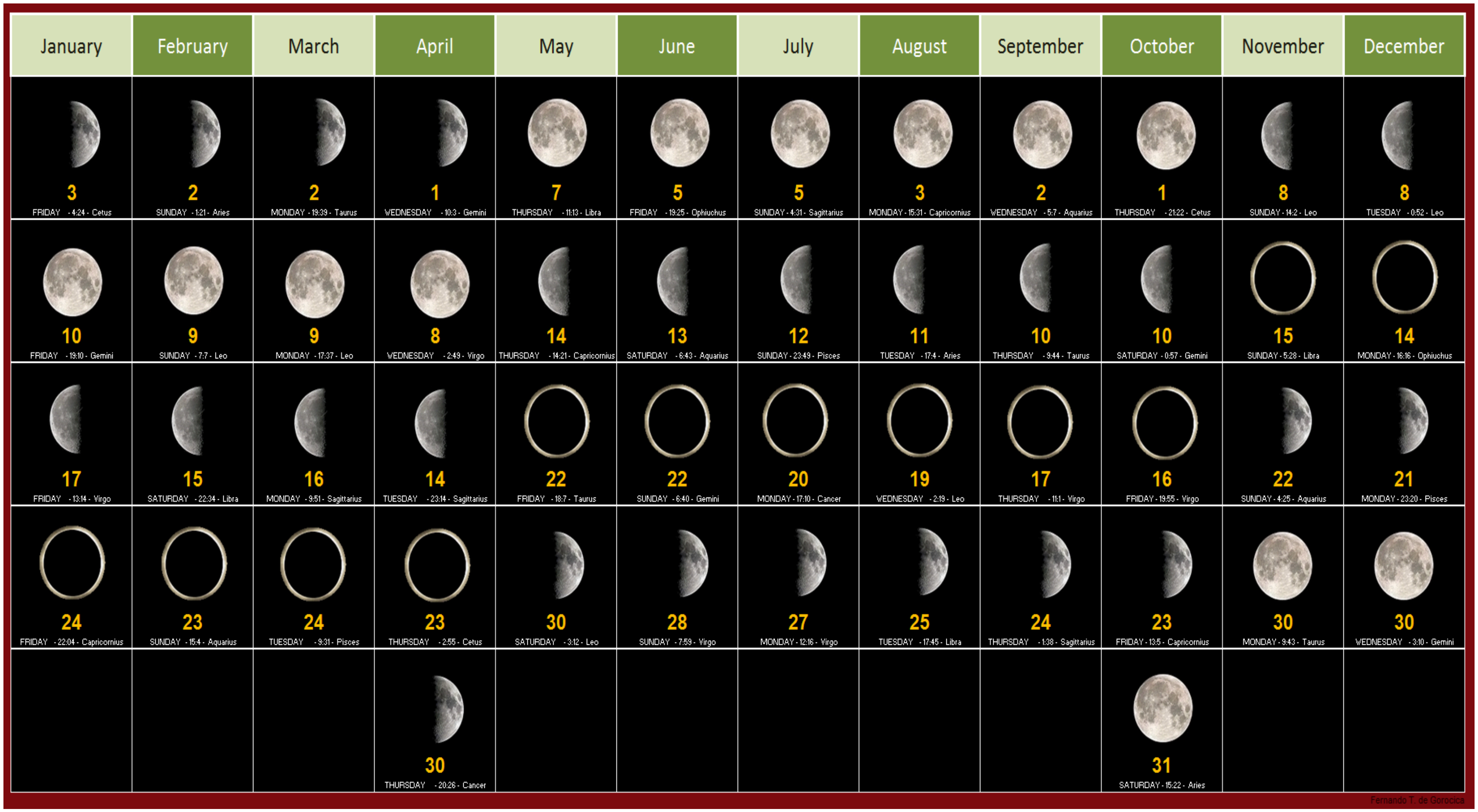


https://open.oregonstate.education/physicsforteachers/chapter/using-powerful-ideas-to-develop-an-explanatory-model-for-the-phases-of-the-moon/

Model intended to be an example, not an exemplar.

Chart of Moon Phases (Monaghan, 2011)

Figure 15



Activity 2 - How do shadows change size?

Students need a small card (the mouse), a large card (the elephant), a ruler, and a flashlight. Students will arrange the cards where the shadows of the elephant (large card) and mouse (small card) are equal in length. Students should record the arrangement that worked.

Which arrangement worked the best? Students need to create a diagram to capture the data which explains how the size and placement of the card, along with the distance in between, affect the size of the shadow.

Next, students will examine the shadows carefully and determine are the shadows all the same shade or are some areas lighter than others? Students should mark the areas on the shadow where it was darker or lighter.

Sun, Earth, Moon Model

Another part of understanding the eclipse is to explore the model of the orbits of the sun, earth, and moon. Utilizing the GRC method,, students will gather information with a brief reading, a short model of questions, and the *Eclipse in a Cup* activity.
Unveiling Celestial Patterns: Exploring the Sun-Earth-Moon System *(German, 2023)*.

1. Students will complete the reading on celestial patterns.
2. Next, students should engage in the following short model of questions:

- What is the system of study?
- What does each part of the model represent in the system?
- How do the parts of the system interact?
- Are the parts of the system to scale? Why or why not?
- What causes the lunar phases?
- Why is there not an eclipse every month?

3. Students will continue to work through the lesson using the Eclipse in a Cup activity. They should only explore the model of lunar eclipses at first. Save the solar eclipse for the next lesson.

Reason

In this section students are evaluating information, analyzing data, using mathematical/computational thinking, constructing explanations, developing arguments, and/or using models to reason, predict, and develop evidence. Often, a class discussion is a part of the learning process. Here are some question prompt starters to assist you (Moulding, 2024)

Questions to initiate Discussion:

- What patterns….? (typically questions about the data in the investigation)
- What caused changes in the system…? (typically a question about the information gathered)
- Why does the …?(typically a question about core ideas and/or crosscutting concepts)
- How does the model …(typically a question about core ideas and/or crosscutting concepts)
- Where have you observed …?(typically a question about applying to analogous phenomena)

The end of the discussion should be a shared explanation across all students in the classroom.The next step is for students to go back to their initial model with the light, shadows, and patterns, and make revisions based on the additional information. Challenge students to incorporate the learning from the Eclipse in a Cup activity to their model as well.

Communicate

The third part of the GRC method, communication, refers to the need of students to communicate the information they gather as well as convey arguments (written and oral) for how the evidence supports or refutes an explanation. They should share the reasoning for their choice of models and the drawing of diagrams that helped make their thinking visible (Moulding, 2024).

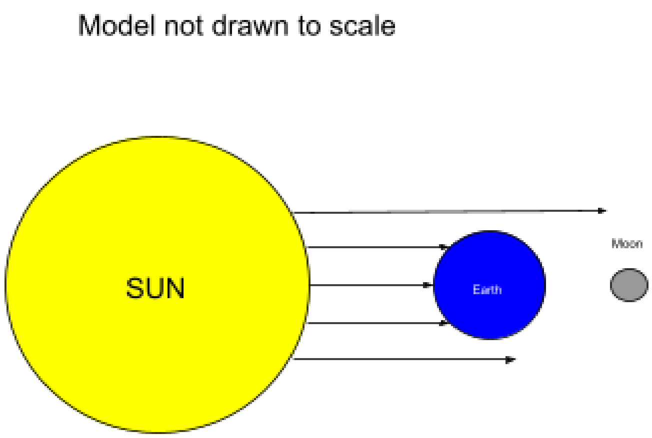
Communication Activity

Students will develop an explanation for the causes of the cyclical pattern of moon phases and include why there is not a lunar eclipse every month. Below is an example student paragraph in

Figure 16. It is not intended to be an exemplar. Following will be question and sentence starters, writing scaffolds, rubrics, and a scoring guide.

Example student paragraph

Figure 16



Hey, fellow space enthusiasts! Have you ever wondered why the moon looks different every night? Let's dig into the secrets of moon phases and figure out why we don't get a lunar eclipse party every month.The moon changes its appearance because it's dancing around the Earth, and the sun's light hits it in different ways.When the moon is between the Earth and the sun, it's like a moon-newborn, all dark. That's our new moon! As the moon moves, we start seeing a small lit-up part, like a crescent. This is the waxing crescent – it's like a cookie with a bite taken out. After a while, half the moon is all bright – that's the first quarter.

Then, it's a full moon when the whole thing is lit up, like a giant glowing cookie. After that, it starts getting smaller – waning gibbous, last quarter, and so on until it's back to a new moon. Now, about lunar eclipses – turns out, they're a bit picky. The Earth, moon, and sun need to be in a straight line for an eclipse to happen as shown in the diagram below. But guess what? The moon's path is a bit tilted, like a twist in the cookie trail. So, most months, the Earth's shadow goes above or below the moon, and there's no eclipse. It's like a super cool lunar eclipse event, but it only happens when everything lines up just right!

Question and Sentence starters for scientific explanations

Figure 17.

Scientific Argumentation (How do you know?)/ Explanation (Why is it so?) Writing Frame

What You Need to Write	Sentence Starters
Make a claim that answers the question you developed or were given.	• I claim that … • The ……. (is, does, etc.)…
Support your claim with evidence from your investigation(s), reading, videos, etc. Use all data that counts as evidence. Include both qualitative and quantitative evidence. Units should be used with quantitative evidence.	• I think this because………. • For example….. • For instance…….. • The evidence is…………. • The data show………. • The data provide evidence that...
Add support from additional evidence you have from your investigation(s), reading, videos, etc..	• In addition,…… • Furthermore,………… • Also,……………….
Add scientific reasoning if required. These are scientific principles that link the claim and evidence. It tells why the data counts as evidence. Be sure to include at least ONE CROSS- CUTTING CONCEPT	• ……….because…………… • I think this because………… • Using (insert crosscutting concept) explains why or how…………..

Provide the <u>claim</u> of another person/group that answers the question you developed or were given.	● Another person or group claims that … ● The ……. (is, does, etc.)…
Provide the evidence for another (different)claim.	● He/She/They think this because………. ● For example….. ● For instance…….. ● The evidence is………… ● The data show………. ● The data provide evidence that
Provide a rebuttal	● Even though …. ● I agree that………., but I cannot agree with………. ● While it is true that…….. ● Admittedly…….. ● Granted……… ● Some people may say…… ● Some people think…..

Evidence, Reason, Claim Scaffold

For this scaffold in Figure 18, students should fill in the evidence first. After filling in for the evidence (you can add or remove the number of rows as needed), students should use the evidence to develop a claim. Focusing students on evidence first, then writing a claim that fits the evidence follows science. Then, reasons connect the evidence to the claim, so reasons are the last to be completed. Another scaffold to assist students with writing scientific reasoning is below.

Figure 18

Evidence	Reason
1.	1.
2.	2.
3.	3.
4.	4.
Claim:	

Evidence	Reason	Claim

Argument Scaffold for Students

This argument scaffold (Figure 19)is useful for when students have their argument outlined (usually on a whiteboard) and shared. Students look for an argument that is different to do a rebuttal.

Figure 19

Question:	
My Claim:	**Others Claim:**
My Evidence:	**Others Evidence:**
Do I want to change my claim: **YES or NO**	
The reason I do/do not want to change my claim.	

Rubric for Communication Activities. Figure 20

Component	Score		
	4	**3**	**2**
Accuracy of claim	Makes a mathematically or scientifically correct claim and completely catches the essence of the investigation	Makes a mathematically or scientifically correct claim and partially catches the essence of the investigation	Makes a mathematically or scientifically incorrect claim
Sufficiency of evidence	Provides more than two pieces of evidence and makes a rebuttal	Provides two pieces of evidence	Provides one piece of evidence
Quality of evidence	Makes an appropriate and adequate explanation completely based on interpretation of investigation data	Makes an appropriate and adequate explanation partially based on interpretation of investigation data	Makes an inappropriate and inadequate explanation or reports data as evidence
The relationship between claim and evidence	Makes a strong and sophisticated connection between claim and evidence. **Uses at least one crosscutting concept.**	Makes a strong connection between claim and evidence	Makes a weak connection between claim and evidence
Presents a rebuttal to another claim	Rebuttal is coherent and provides appropriate evidence and explanation for disagreement	Rebuttal is somewhat incomplete with explanation	Makes a weak rebuttal with incomplete explanation not based on evidence.

		only partially based on evidence.	
Multimode representation	Uses more than one mode (text) in explaining the concept(s) and it is tied to the text.	Uses more than one mode (text) in explaining the concept(s) but does so separately from text	Only uses one mode (text) to explain the concept in writing
Audience language	Language is appropriate, easy to understand, and meets the demands of the audience.	Although clearly aware of the audience, the writer only occasionally speaks directly to that audience.	Does not consider the audience's language
Score			

Lesson 2 Solar Eclipse

The Cause of a Solar Eclipse

Use a couple of the following activities to get students thinking about how the locations of the Earth, Moon, and Sun affect the possibility of having a solar eclipse. Each model has a different emphasis to assist students in developing a mental image of what happens during a solar eclipse.

Cosmic Coincidence : Eclipse Science Activity | Exploratorium
Eclipse to Scale: Eclipse Science Activity | Exploratorium
Make a Ring Light Eclipse: Science Activity | Exploratorium
Make an Eclipse: Eclipse Activity | Exploratorium

Regardless of the number of activities students engage in, ask the following questions.

1. What is the system of study?
2. What does each part of the model represent of the system?
3. How do the parts of the system interact?
4. Are the parts of the system to scale? Why or why not?
5. What causes the lunar phases?

Once students have completed the activities, I would have them outside on a sunny day to spot the sun. This activity is good practice for spotting the solar eclipse when it happens.

Spot the Sun: Make a Pinhole Sun Viewer | Exploratorium
Making-a-Pinhole-Viewer.pdf (b-cdn.net)

Gazing Protection

When gazing at the solar eclipse in person, it is extremely important to protect the eyes when looking at the sun. Never look directly at the Sun without proper eye protection. **ISO approved solar eclipse viewing glasses** work great for viewing a solar eclipse. Also, **DO NOT REUSE THE GLASSES FROM THE PREVIOUS ECLIPSE.** They no longer have proper protection.

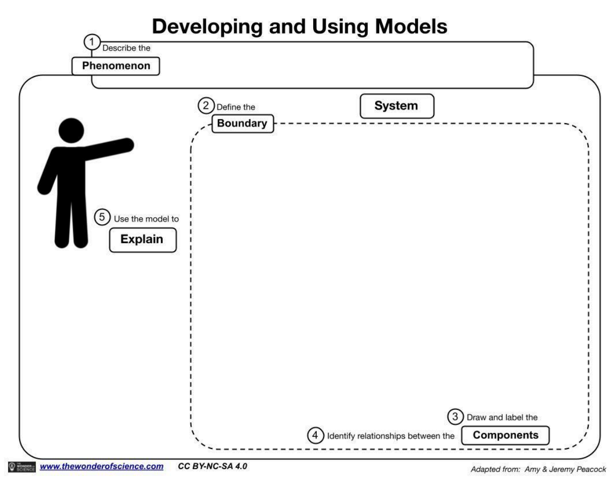
However, sometimes with smaller children, the glasses might not fit securely around the face and over the ears well enough to provide maximum eye protection. Therefore, it is a good idea to extend the coverage area of the glasses by attaching them to a paper plate to provide that added protection.

Integration of Solar and Lunar Eclipse information

An example of how to integrate this information with prior learning on the Lunar Eclipses (Fig.21).

- Develop a model that explains the cause of a solar eclipse.
- Explain why it does not happen each month.

Figure 21



Cross-curricular Integration

History

Impact on Society

Why do solar eclipses occur, and what is their impact on society? The following lesson idea integrates readings from the historical and cultural perspective about the solar eclipse. In small groups, students can brainstorm their response to the following prompt:

How do solar eclipses impact society?
Choices of readings:
How the 1919 Solar Eclipse Proved Einstein's Theory of General Relativity by Darcy Pattison (2021, December 23)
When the Sun Goes Dark by Andrew Fraknoi and Dennis Schatz (2017)
Totality! An Eclipse Guide in Rhyme and Science by Jeffrey Bennett (2022, September 14)
A Few Beautiful Minutes Experiencing a Solar Eclipse by Kate Allen Fox (2023, September 26)

Reading or ELA

Myths

Activity 1) Students will read or research various myths about solar eclipses from around the world. Example Question for students:

> "Set aside what you've learned about eclipses and what science has taught us. Put yourself in the shoes of an ancient civilization. Which myth would you have likely believed? Explain which myth seems the most possible to you and why you have been likely to believe the myth?"

Poetry

Activity 2) Students will read the poem, *The Eclipse (......),* by Deborah Trustman and look for figurative language and tone.

Articles - Science

Activity 3) Students will read articles about animal behavior during an eclipse.

- Students plan their own investigation to conduct during the eclipse.
- Students will create a report with the results.
- Students will gather all data from classmates.
- Students will determine which animal's behavior was affected the most.

Sources of Articles -

Fazekas, A. (2017). Surprising Ways Animals React to Solar Eclipses. *National Geographic.* https://www.nationalgeographic.com/science/article/animals-react-total-solar-eclipse-august-space-science

Keck , M. (2023). Unlocking the Mysteries of Animal Behavior During Cosmic Events. *News at IU Indiana-University* During Cosmic Events https://news.iu.edu/live/news/31916-unlocking-the-mysteries-of-animal-behavior-during#:~:text=Animals%20like%20opossums%2C%20bats%20and,could%20signal%20that%20it's%20bedtim

St. Fleur, N. (2018). The Moon Eclipsed the Sun. Then the Bees Stopped Buzzing. *The New York Times*, https://www.nytimes.com/2018/10/10/science/bees-eclipse-buzzing.html#:~:text=The%20researchers%20found%20that%20while,eclipse%20occurred%20in%20their%20location.

Fine Arts

Activity 1

To set the tone for viewing the solar eclipse, consider playing music. One classical selection by Strauss, has been used in movies. This particular link is the short, well-known part of his longer piece. (Known as the *2001 Space Odysse*y theme and depicts the sunrise. This link is just for the 2 min. famous tune from the movie. This particular conductor is world-renown and amazing).
https://youtu.be/Szdziw4tI9o

Also sprach Zarathustra Strauss

Activity 2

In addition to setting the mood, students can be asked to consider what about the music that they hear might represent the appearing of the sun and why? Connecting music concepts such as pitch and dynamics can inform the comprehension of the eclipse as well. Pitches that move to higher sounds can indicate the appearing of the sun. A louder dynamic, or volume of sound, can indicate the intensity of the presence of the full sun, etc. Having students in discussion pairs and groups to explain their reasoning or for them to draw what they think of when they listen to the music are additional activities.

Activity 3

As students study about the sun, they will realize it is actually a large star. One unique music selection that depicts the shimmering of stars using the science concept of volume and water, is *The Stars* by Esenvalds https://youtu.be/KWdjF2K2bZA. Refer to Appendix A for more details.

Math and Science

Gather

Why does a solar eclipse not occur every month? What does a Solar Eclipse Look Like?

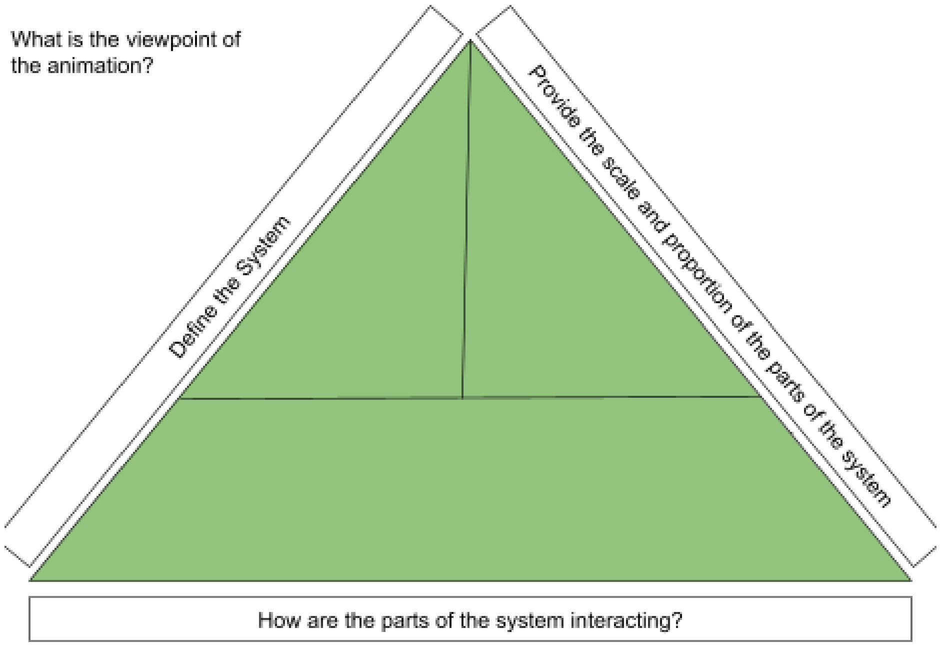
Solar System Animation

- Have students watch the solar system animation three times (it is short, 30 seconds) 2017 Imagery of the total solar eclipse as captured by NASA's Earth Polychromatic Imaging Camera (EPIC) onboard NOAA's Deep Space Climate Observatory (DSCOVR). Again view three times (it is short, 28 seconds).

- Students need to fill out the Rhetorical Triangle (Fig. 22). Maybe use two rhetorical triangles, one for each media clip.

- Each time a student looks at the animation with a different lens and writes down what they observe.

Figure 22



What about effects?

Head back to the brainstorming of questions regarding the impact of eclipses on society from the history section in the cross-curricular integration. Organize the questions into groups. For example, one group might include questions that ask about the possible effects eclipses have on the environment. Another group of questions might focus on the effect of a solar eclipse on wildlife. Measure the changes in animal behavior directly prior to the eclipse and during the eclipse on April 8. 2024.

Interests in participating in a citizen science project could use Eclipse Soundscapes which has several options available for teachers to facilitate research with their students.

Reasoning

Predicting solar eclipses

What do we use to predict solar eclipses? Do solar eclipses occur with a repeating pattern that allows us to use the pattern to predict future eclipses? This file contains all of the eclipses for the 21st century from 2001 to the present as well as the predicted future eclipses through the year 2100. The file format is a .CSV which allows it to be uploaded into CODAP for analysis.

Analysis in CODAP

1. Upload the file format to CODAP, specifically Untitled Document - CODAP (concord.org). Any data analysis tool works for this part of the lesson. The benefit of CODAP is its ease in allowing students to explore the data.
2. Create graphs that can assist in discerning if a pattern exists in solar eclipses.
3. Keep track of the different graphs produced.
4. Is there a repeating pattern for solar eclipses? Yes or No
5. If not, what do we use to make the predictions?

Analyzing model data Activity

This activity provides a bit more information to assist in deciding the pattern for predicting solar eclipses (Fig. 23). Use a quarter and a nickel to represent the Sun and Moon (not to scale).

Model 1: Moon at Perigee. The Moon is closest to the Earth in its orbit known as perigee. Use a quarter to represent the Moon.

1. Place the disk representing the Sun on s1 of the Sun path, and the disk representing the Moon on m1 of the Moon path.
2. Move both disks simultaneously from s1 to s2 and m1 to m2.
3. Then from s2 to s3 and m2 to m3.
4. Then from s3 to s4 and m3 to m4.
5. Then from point s4 to s5 and m4 to m5.
6. Record your observations at each point in a data table. Provide the point, if an eclipse occurs (total or partial), and reasoning.

Model 2: Moon at Apogee. The Moon is the furthest from the Earth in its orbit. Use a nickel to represent the Moon and repeat the process in Model 1.

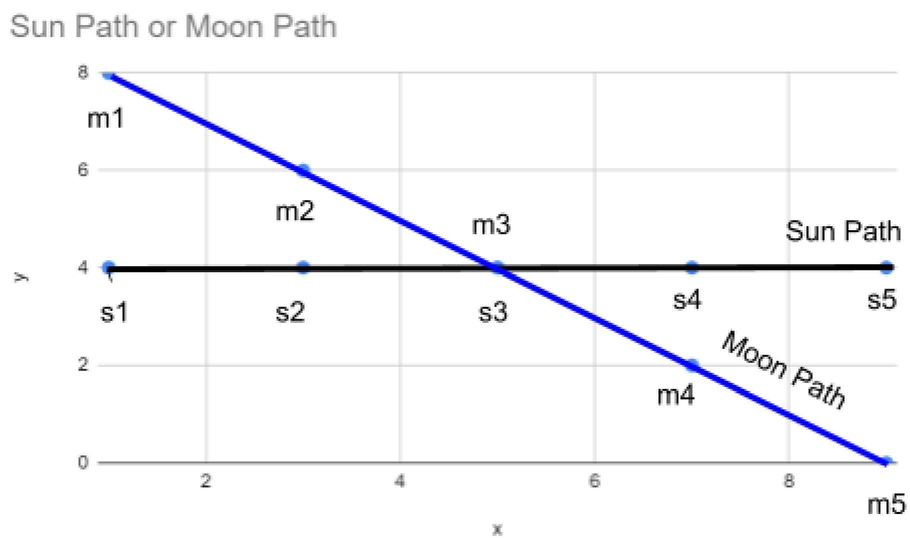
Model 3: Other positions. Sometimes the Moon crosses the path of the Sun in the sky, the Moon is either too early or too late to have them overlap. Use the quarter-sized disk for the Moon.

1. Place the Sun at point s1.
2. Place the Moon at point m2.
3. Move both disks simultaneously from s1 to s2 and m2 to m3.
4. Then from s2 to s3 and m3 to m4
5. Then s3 to s4 and m4 to m5.

6. Record your observations at each point in a data table. Provide the point, if an eclipse occurs(total or partial), and reasoning.

Graph of the Sun's path and Moon's path.

Figure 23



Communicate

Students will write an argument stating which of the following claims best explains why we do not have solar eclipses every month (Appendix B has scaffolds and rubrics to assist).

Example Claims

Claim 1: Solar eclipses can only occur at the New Moon, when the Moon is between the Earth and Sun. But not every New Moon produces an eclipse. The Moon's orbit is slightly tilted, which causes the Moon's shadow to miss the Earth during most new moons.

Claim 2: The Moon's orbit is elliptical, which means sometimes the Moon is closer to Earth than others, which affects if we experience an eclipse and the type of eclipse.

Claim 3: The Moon's shadow is very small, compared to an object like Earth, so in any given location on Earth, a total solar eclipse happens only once every hundred years or so, though for selected locations they can occur as little as a few years apart. The part of Earth that the shadow actually passes over is fairly small, sometimes passing only over small, scarcely populated swatches of land, making observations more rare.

Appendix A - Lesson Ideas Using Music

Introduction:

There are several pieces of classical music that either reference or depict the solar eclipse or the solar system. These pieces have value on their own for music study, but they also can be great tools for connecting with language arts, science, and history. Below are a few ideas:

The Moon:

In a solar eclipse, the moon blocks the sun. There are classical pieces of music that refer to the moon. These first two piano solos are quiet and slower which could be background music in the wait for the eclipse. These particular pianists do an amazing job!

Moonlight Sonata Piano sonata No.14 in C# min. Beethoven

beautiful and quiet but continuous movement
https://youtu.be/-VmQNKaOeEw

Clair de la lune beautiful piece from impressionist era Debussy
https://youtu.be/RhW5Kmqjk_Y?si=nfIf6xnpflz7H-eF

The next two songs refer to the moon in stories of love.

Vaga Luna Bellini
beautiful song about the moon delivering a love letter with the vocal soloist singing in Italian
https://youtu.be/AwA7PVc3sBE

"Song to the Moon" from the opera, *Rusalka* Dvorak
This particular clip shows the vocalist in costume and performed in the opera setting (3 min.)
https://youtu.be/hzgQPjbDTMM

The Sun:

"Morning Mood" from *Peer Gynt* is orchestral and uplifting Grieg
grieg morning peer gynt - Google Search

Also sprach Zarathustra Strauss

(known as the *2001 space odysse*y theme and depicts the sunrise. This link is just for the 2 min. famous tune from the movie. This particular conductor is world-renown and amazing).

https://youtu.be/Szdziw4tI9o

The Planets:

Some planets may become visible during the totality of the eclipse such as Mercury, Venus, Mars, and Jupiter. A piece that has songs depicting the planets:

The Planets	Holst	https://youtu.be/Isic2Z2e2xs
“Mars” sounds like preparing for battle		(7min.)
“Venus” is slow and peaceful		(7min.)
“Mercury” sounds like cartoon music		(6min.)
“Jupiter” in particular is upbeat and bright		(8min.)

The Stars:

Really unique choral piece where the instruments accompanying it **are tuned water glasses** that create a shimmering effect. This science connection with reference to volume, the transfer of sound through water, the differing amounts of water create different pitches, acoustics, etc. is amazing! This link shows a choir singing and playing the glasses. Super cool!

Stars Esenvalds https://youtu.be/KWdjF2K2bZA

The Solar Eclipse:

There are pieces about the solar eclipse event or uses the imagery of the eclipse in their writings such as the following:

Handel’s “Total Eclipse” from *Samson* opera (3min.)

https://youtu.be/Mw1UyFzxPBk

This is sung in English and depicts how the heart feels in desperation. The eclipse is connected with and describes that despair.

Prince Igor, opera by Alexander Borodin - The Prologue (begin at 15:00 – 23:00)
Kirov Opera: Alexander Borodin - Prince Igor / Князь Игорь (Part 1) - YouTube

Alexander Borodin's opera tells the story of a total solar eclipse in 1185 that was sighted by the Prince and his army during a campaign against the Polovtsians. The eclipse was considered a bad omen and figures prominently in the story. The beginning of the opera, just the first few minutes, contains this as a backdrop for the rest of the opera.

[This area is modern day Ukraine. Even in the 12th century, this land area was in dispute of being in Russian control or not. Fascinating modern connection to the culture of politics and war.)

Appendix B - Additional Resources

https://www.teachingchannel.com/k12-hub/blog/solar-eclipse-curriculum/

https://eclipse.aas.org/sites/eclipse.aas.org/files/Fulco_S%26C_TSE2017_4.pdf

Websites

My NASA Data Eclipse Resources:
Solar Eclipse Mini Lessons | MyNASAData

Exploratorium:
Solar Eclipse Activities - Teacher Tested | Exploratorium

Mid America Science Museum:
2024 Eclipse Admission - Mid-America Science Museum (midamericamuseum.org)

TCEA:
Solar Eclipse Activities, Resources, and Safety Information • TechNotes Blog (tcea.org)

National Science Teaching Association (NSTA):
Solar Eclipse | NSTA

ISTE:
ISTE | 7 resources for teaching the solar eclipse

Generation Genius Subscription:
Solar & Lunar Eclipses Video for Kids | 6th, 7th & 8th Grade Science (generationgenius.com)

Videos

National Geographic:
Solar Eclipse 101 | National Geographic - YouTube

PBS Learning Media:
Solar Eclipses | PBS LearningMedia

NASA Space Place:
What Is a Solar Eclipse? - YouTube

Khan Academy:
Solar eclipses (video) | Khan Academy

Dr. Binocs- School Tube:
Solar Eclipse The Dr. Binocs Show Educational Videos For Kids (schooltube.com)

Books

Library of Congress:
Books for Young Readers - Solar Eclipses: A Reference Guide - Research Guides at Library of Congress (loc.gov)

Great American Eclipse:
Eclipse books — Great American Eclipse

EPIC:
Solar Eclipse Children's Book Collection | Discover Epic Children's Books, Audiobooks, Videos & More (getepic.com)

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