

*of gravity
and
light*



*Teaching
the Science
of Our Solar
System
With Creativity
and Curiosity*

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ABOUT THIS CURRICULUM

Of Gravity and Light: Teaching the Science of Our Solar System With Creativity and Curiosity is a modular science curriculum that meets Next Generation Science Standards. Learning materials serve as a companion to Beau Kenyon's new ballet ***Of Gravity and Light***, which draws from the science of our solar system as source material for his new work. Music, dance, and media arts are integrated with hands-on activities and multimedia resources developed by NASA, GBH, and Iowa PBS. Students explore the science of our solar system through creativity and artwork while using these same tools to demonstrate understanding of a scientific concept. All four learning modules draw examples from ***Of Gravity and Light*** as examples of how professional artists interpret science through their respective disciplines while prompting learners to use the creative arts to demonstrate understanding of scientific concepts.

Music, dance, and visual art are integrated with hands-on activities and multimedia resources developed by NASA, GBH, and Iowa PBS. Students explore the science of our solar system through creativity and artwork while learning that these same tools demonstrate understanding of a scientific concept. All four curriculum modules draw examples from ***Of Gravity and Light*** as examples of how professional artists interpret science through their respective disciplines.

The curriculum is free for all, published through Iowa State University, and distributed by 4-H Youth Development, Iowa PBS/PBS Learning Media, and Ballet Des Moines. A detail below lists all partners engaged to create ***Of Gravity and Light*** and the companion curriculum. We are grateful for our partnerships.

National Partners

GBH
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Program Engagement Partner

A NOTE TO EDUCATORS

Of Gravity and Light: Teaching the Science of Our Solar System With Creativity and Curiosity is a modular science curriculum that meets National Middle School and Next Generation Science Standards and integrates science with art and the humanities. The curriculum was authored by Beau Kenyon and Dr. Sara Nelson (Iowa State University and the Iowa NASA Space Grant Consortium) with support from Iowa PBS Learning Media and advisors, Dr. Shawn Stevens (GBH Learning Media) and Christina Farrell (Arts Integration Specialist). This curriculum is free for all, published through Iowa State University, and distributed by 4-H Youth Development and Iowa PBS.

This curriculum is founded on the following principles:

- Joyful learning fosters deeper and more meaningful understanding
- To study the science of the solar system, we must also understand interdependent systems and the relationships between bodies of our solar system
- Art, creativity, and social relationships provide relevance and useful examples of systems and interdependent relationships
- Engaging academics, positive learning environments, and developmentally responsive teaching heighten a student's ability to be invested in their own learning
- Curiosity, creativity, and collaboration foster a lifetime of learning

Just as composer Beau Kenyon's *Of Gravity and Light* interprets the science of the solar system in an hour long contemporary ballet, so are these lessons equally rooted in science, creativity, and a social-emotional intelligence. Through this staged ballet and companion science curriculum, the solar system becomes a metaphor for relationships, a guide to understanding civilizations, and a source of inspiration for who we wish to be in this world. It paves the way for deeper understanding of specific big, abstract scientific concepts while helping us grow into more empathetic and compassionate humans.

A NOTE TO EDUCATORS

How does it work?

Students learn through a combination of multimedia and hands-on activities that integrate music, movement, and visual art with lessons and resources from NASA, WGBH, and PBS. Students explore the science of our solar system through creativity and artwork while learning how these same tools can be used to demonstrate understanding of a scientific concept. All four curriculum modules draw examples from *Of Gravity and Light* as examples of how professional artists interpret science. Within each module, students are invited to engage with guiding questions, ultimately creating their own questions to guide learning, support curiosity, and fuel intrinsic motivation.

How do we know it works?

Student self-reflection and discussion are complemented by teacher observation and evaluation. Students are held accountable by the teacher, their peers, and themselves. Learners engage with trusted hands-on science activities that have been developed by NASA, PBS, and GBH while consistently reflecting on their learning, presenting to the class, and (eventually) tested on foundational concepts. Each module is closely tied to the National Middle School Standards, Social Emotional Learning Standards, and developmentally appropriate Fine and Performing Arts Standards. In addition to academic success, the qualitative marker for success is noted by a student's level of focus, curiosity, engagement, and peer-to-peer collaboration.

ABOUT OF GRAVITY AND LIGHT

Of Gravity and Light is a contemporary ballet and orchestral concert work by composer Beau Kenyon and produced by Ballet Des Moines. The work is set in 2 parts for contemporary dance, large scale projection, choir and nine musicians (soprano voice, alto voice, baritone voice, clarinet, horn, violin, viola, cello, piano)

Composition & Concept | Beau Kenyon

Choreography | Tom Mattingly

Video Projection | Yu-Wen Wu

Conductor | Tim McMillin

Dramaturgy | Ilya Vidrin

Costume Design | Sarah Dornink

Light Design | Catherine Girardi

The 50-minute work interprets the science of the solar system, translating astrophysical concepts into musical structures and choreographed movement. The comprehensive work expands access and creates bridges between contemporary performing arts and the science of space. The project was founded on collaboration, working with artists and educators and partnering with organizations throughout Iowa and across the country.

FROM THE COMPOSER AND CREATOR

I believe in science. That the universe and our experiences in it are rooted in the scientific disciplines, intertwined to encapsulate seemingly endless beauty and wonder. We have all been invited on a lifelong quest to make meaning of the world around us – a journey that necessitates more than the sciences to fully comprehend. How can we truly understand the environmental sciences without poetry? How would we begin to comprehend neuro-cognitive functions in the absence of creativity? How could we possibly explore the science of space without our imaginations? without music?

*I built **Of Gravity and Light** on the scientific principles of our solar system, but as much as this ballet maps musical systems onto our solar system, it is not purely about the science, alone. The science also provides a series of rich metaphors and questions to explore. As this piece progresses, I would ask you to consider the title of each movement (phrases that were lifted verbatim from scientific texts) and contemplate what anchored light means to you. I would also invite you to consider how our lived experiences are comprised of gravity and light – how these two seemingly simple and familiar concepts are so complex in and of themselves – working together to pull us down, root our feet to stand upright, illuminate our consciousness, breath light onto our planet, and pull us into each others' orbits. **Of Gravity and Light** emerged from these ideas and questions to create an incredibly personal new work, built from a language of scientific experiences that are universally experienced*

*As this piece progresses, I would ask you to consider the title of each movement (phrases that were lifted verbatim from scientific texts) and contemplate what anchored light means to you. I would also invite you to consider in what ways our lived experiences have all been comprised of gravity and light – how these two seemingly simple and familiar concepts are so complex in and of themselves – working together to pull us down, root our feet to stand upright, illuminate our consciousness, breath light onto our planet, and pull us into each others' orbits. **Of Gravity and Light** emerged from these ideas and questions to create an incredibly personal new work, built from a language of scientific experiences that are universally experienced.*

Of Gravity and Light grew out of a constellation of collaborators, partnerships, and advisors – I am incredibly thankful to everyone who contributed energy and inspiration towards this vision, who has provided space and time for dialogue and creativity, and who has collectively built an environment for trust and curiosity.

ABOUT BEAU KENYON

After earning music composition degrees from Berklee College of Music (B.M., 2004) and Tufts University (M.A., 2007), Beau Kenyon dedicated a decade to research in the fields of cognitive neuroscience (pub. Behavioral and Neural Correlates of Executive Functioning in Musicians and Non-Musicians. PLoS ONE. 2014), curiosity-based teaching practices, and community engagement strategies (pub. Listening to the City: Community Research and Action through Sound and Story. MIT Press. 2018). In 2016, Kenyon became the first composer-in-residence for the Boston Public Library (and all the men and women merely players for mixed chamber ensemble and four dancers). Kenyon has since created a portfolio of performance installations for institutions, including the Museum of Fine Arts Boston. He has received support from the New England Foundation for the Arts, Northeastern Center for the Arts, and Andrew W. Mellon Foundation. His permanent multimedia sculpture, *River Constellation* (2019, in collaboration with sculptor Natalia Zubko) responds to the landscape and soundscape of the Des Moines Water Works Park. *Tell Me* (2020, in collaboration with artist Yu-Wen Wu) is a single channel video, featuring a film score of recorded stories from first-generation refugees, originally exhibited at SITE Santa Fe.

In 2017, Beau Kenyon founded The Oakley Collective for Arts + Research, a non-profit consulting firm that supports organizations at specific points in their operational growth – building audience engagement strategies, innovative operational systems, and cross institutional partnerships that generate measurable outcomes in sustainability, impact, and accountability. Kenyon’s work functions at the intersection of tactical support, strategic planning, and professional development. His approach relies on collaborative learning systems, curiosity fueled planning sessions, and cross-institutional partnerships. Beau Kenyon is also currently on faculty at the College of Arts, Media + Design at Northeastern University, where he teaches graduate coursework in arts administration and cultural entrepreneurship. www.beaukenyon.com | www.oakleycollective.org

MODULE 1

PATTERNS OF THE

EARTH AND ITS MOON

Of Gravity and Light Movement I
*and the same face became tidally locked,
forever pointed toward Earth*

Next Generation Science Standards

MS-ESS1-1

Develop and use a model, exploring the cyclical patterns of the Earth-Moon System

MS-ESS1-2

Develop a model to describe the role of gravity in motions of the Earth-Moon System

MS-ESS1-3

Interpret data to determine properties of the Earth's Moon Orbit (orbital radius)



Image from **Of Gravity and Light** , mvmt III

STUDENTS WILL



PARTICIPATE IN ARTS INTEGRATED INTRODUCTORY LESSONS (CREATIVITY)



EXPLORE HANDS-ON MODEL-BUILDING ACTIVITIES (CREATIVITY)



DEVELOP RESEARCH QUESTIONS THAT CONNECT TO THE DRIVING QUESTION (RESEARCH)



INVESTIGATE MULTIMEDIA INTRODUCTIONS WITH MINI-LESSONS (RESEARCH)



ACCESS ENRICHMENT RESOURCES FOR FURTHER SUMMATION AND EXTENSION (RESEARCH)



ENGAGE WITH DISCUSSION QUESTION BOARD AND INDIVIDUAL SCIENCE JOURNALS THROUGHOUT THE MODULES (FORMATIVE ASSESSMENT)



CREATE, EXPLAIN, AND PRESENT AN ORIGINAL FINAL ARTWORK AS A CONCEPTUAL MODEL OF ONE BIG IDEA FROM THIS MODULE (SUMMATIVE ASSESSMENT)

STUDENTS WILL USE



COMPUTERS/TABLETS AND THE INTERNET



RESEARCH JOURNAL



A CLASSROOM DRIVING QUESTION BOARD



ARTS AND CRAFTS MATERIALS

BIG IDEAS

A note to educators: *These are the primary concepts explored in this module and should guide instruction. **Do not** begin the module by presenting these concepts. Instead, let students come to these conclusions through investigation, inquiry, discussion, and reflection throughout the inquiry-led module. Once students draw a conclusion – post the corresponding Big Idea in your classroom.*

Gravity is what holds the moon in orbit around the Earth. **(SCIENCE)**

Cyclic patterns of the moon can be observed from Earth. Certain characteristics, such as libration and tidal lock, are a result of relationship between the Moon's orbit and rotation in relationship to the Earth. **(SCIENCE)**

Music, dance, and visual art can serve as models to better understand concepts like rotation and orbit while also exploring the physical properties of the moon, itself. **(CREATIVITY)**

Dance/Movement is a form of embodied research that can capture our understanding of gravity – What happens when we allow gravity to weigh us down? How does it feel to work against gravity to lift ourselves upright? To lift others up? **(CREATIVITY)**

Non-traditional sounds, like breathing and page-turns can be considered music and musical instruments. **(CREATIVITY)**

Gravity and its principles can also take on an emotional or metaphorical meaning – exploring ideas of gravity/emotional weight, orbit/importance and timing, and scale, distance, and mass as it relates to hierarchy of needs or emotional responses to situations. **(SOCIAL-EMOTIONAL LEARNING)**

Models can be used to represent systems and patterns. *Of Gravity and Light* is a kind of model that represents systems and patterns of the solar system. The piece is held together by a central theme and concept/gravity which then comes to life in an interdependent system of parts – people, performers, and artists who orbit/work together in different levels of frequency. **(SYSTEMS)**

ARTFUL INTRODUCTION



creativity

A note to educators: This exercise immerses students in the scientific concept through creativity, critical thinking, and embodiment as a form of investigation and research. This introduction should be relatively brief, provide a foundation for exploration, plant seeds for curiosity, and align the classroom in a social-emotional learning community.

Examine

the title of this movement. What does “and the same face became tidally locked, forever pointed toward Earth” mean to you? What does it mean to physically gaze at and study something or someone? What does it mean to keep your mind constantly focused on a single thing, idea, or person? What do you think this specific movement is about? Why do you think that?

Explore

Sit up straight in your chair, feet planted on the ground and hands gently resting on your knees. Check in with the various parts of your body. Notice the sounds in and beyond the classroom. Notice the downward pull on your body, your shoulders, your hands, your head. Now take in a deep breath (5 seconds), hold (3 seconds), audibly breath out (5 seconds). What do you notice about your body? Your chest and diaphragm? Your shoulders? Your face? Repeat this exercise as needed

Now slowly raise your hands off of your knees and slowly rest them back on your knees. How does the action of one limb affect other parts of your body? Do other parts of your body compensate, move, shift? Lift one leg slightly off the floor. Slowly lift your foot off the floor, hold it there, and set it down. What do you notice?

Take a moment to freely explore moving your hands/arms and feet/legs. How is gravity affecting your experience? Describe how your physical body is an interconnected system of parts. Your body is a system, made up of a collection of parts. Identify as many parts of your body needed to complete the entire exercise (internal and external). Compare the weight of your head with your hand, which one felt a stronger gravitational pull? Compare your legs to your head.



Record findings in your
Student Research Journal

ARTFUL INTRODUCTION



Listen and Watch

Of Gravity and Light, Movement I: and the same face became tidally locked, forever pointed toward Earth).




Respond

This piece explores our emotional response to a scientific event as well as the science, itself – what do you think is the relationship between tidal lock and lunar phases? Why do you think that? Why do you think the composer chose to interpret science in this way? Record findings in your **Student Research Journal**.

QUESTION

Research



A note to educators: This lesson uses the **Driving Question Board**  to help students track their learning, prompt classroom discussion, and develop sub-questions questions. The overarching question is a “sneaky” entry point to the Big Ideas, intending to spark interest and curiosity.



DRIVING QUESTION:

WHY DOES THE SAME SIDE OF THE MOON ALWAYS FACE THE EARTH?

Create a prediction for the Driving Question:

THINK: Write the question and individual predictions in their Research Journal.

PAIR: Share entries of the Research Journal, uncover 3 new questions together, and compare predictions. What do you notice? What do you think you know? What seems completely unknown? What are you curious about?

SHARE: Contribute to the classroom *Driving Question Board* in a teacher-facilitated discussion or independently.

Sub-questions may organically come from students. Teachers may wish to facilitate this lesson by volunteering sub-questions. Examples include:

- How does mass affect gravitational pull? Why do you think that?
- What is the difference between orbit and rotation? How are these concepts related?
- Does the moon orbit and rotate?
- Does everyone on Earth see the same face of the moon?

DO/EXPLORE



MEDIA INVESTIGATION



Students search for clues and information to further their learning while engaging with interactive media to better understand the Moon and its properties.



Earth's Moon, Our Natural Satellite | NASA

https://solarsystem.nasa.gov/moons/earths-moon/in-depth/#otp_orbit_and_rotation

HANDS-ON LESSONS



Students work in pairs or small groups to build a model of the Earth-Moon System



Modeling the Earth-Moon System | NASA JPL

In this activity, students will analyze and interpret data to make a scale model of the Earth-sun-moon system in a hands-on activity to begin exploring and modeling the Solar System. Using an assortment of materials, students will analyze and interpret data to build a model of the Earth-Moon system.

<https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-earth-moon-system/>

MEDIA EXTENSIONS



Students can access these short media resources for further investigation, deeper understanding, or a homework/prework activity.



Rotations in Space | PBS

Astronaut Jeffrey Williams demonstrates rotation of symmetrical and asymmetrical objects from his aircraft in space.

https://contrib.pbslearningmedia.org/WGBH/conv18/npe11_int_spacerotations/page_02.html



Lunar Phases and Libration | NASA

This timelapse video on YouTube provides a beautiful view of the lunar phases as well as the gentle nodding of the lunar libration.

https://www.youtube.com/watch?v=3f_21N3wcX8



Earth's Moon: Why One Side Always Faces Us | Conceptual Academy

This curriculum extension provides more insight into *Of Gravity and Light, Movement I: and the same face became tidally locked, forever pointed toward Earth.*

https://www.youtube.com/watch?v=j91XTV_p9pc

REFLECT



Formative
Assessment



Review the **Driving Question Board** and **Research Journals**.

How did your results compare to your predictions? Make any necessary corrections.

What new questions do you now have?

What did the activities teach you about the moon?

What key words are you using to talk about this concept? What questions do you have about key words shared in the Big Ideas?

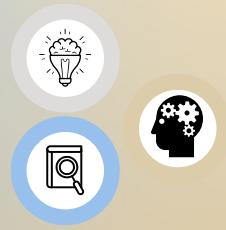


View Interview | Beau Kenyon describes his process and why he chose to represent gravity in this way

View Interview | Tim McMillin describes his role in relation to the music ensemble (he is the sun)

View Interview | Ilya Vidrin speaks how gravity relates to the connection we feel between each other

APPLY



Listen/Watch (*Of Gravity and Light, Movement I: and the same face became tidally locked, forever pointed toward Earth*). Video Clip is of the staged performance of Tom Mattingly's choreography and Yu-Wen Wu's video installation, paired with Beau Kenyon's musical score. Think about how you would use dance or movement to represent express lunar phases.



1. How many instruments do you hear? Why do you think he chose to use nontraditional sounds for this first movement? What do these sounds remind you of?
2. The composer uses non-traditional sounds, like breathing from the choir. How might these sounds be metaphors for patterns or characteristics of the moon? What did it make you think of?
3. What instruments or sounds would you use?
4. What kind of movement would you use?



Image from **Of Gravity and Light, mvmt I**

APPLY



In small groups, partners, or individually, select one specific science concept we explored in this module. Make a plan on how you would represent that scientific idea through music, dance, or video. Feeling stuck?



Use your **Research Journal** and the **Discussion Question Board** for ideas

ENVISION

1. Choose one of the Big Ideas (SCIENCE).
2. Brainstorm a list of ways you would represent this Big Idea with music, dance, or visual art.
3. Sketch/Outline 2- 3 ideas and discuss with your group, which one you will decide to create.

PLAN

1. Choose one idea, write 5-7 sentences describing the creative/science project
 - a. What scientific concept will you interpret through art? (be specific)
 - b. What artform(s) will you use?
 - c. Why will you use those specific artforms? What do they represent?
 - d. Include a sketch
2. Who will be responsible for which part of the project?
3. How will you know if the project is “successful”?
4. Consult with your teacher

CREATE, EXPLAIN AND PRESENT

1. Collaborate or work independently to create your final project
2. Present your creative project to the class and explain exactly how it relates to the science of the Big Idea(s) of the Module.

MORE ABOUT

*Of Gravity and Light, Movement I:
and the same face became tidally locked,
forever pointed toward Earth*



Stills from Yu-Wen Wu's video projection from **Of Gravity and Light, mvmt I**

The opening scene from **Of Gravity and Light** is composed for alto voice, clarinet, and cello and choir and also features non-traditional sounds (page turns, match strikes, and the sound of breathing). This scene investigates the orbital characteristics between the Earth and Moon (such as tidal lock and lunar liberation) in 8 minutes. Shifting between observable characteristics of the Moon and the Moon, itself, this scene presents an opportunity to explore the emotional metaphor of seeing only one face of the moon as well as the science that explains why this happens. The scene also provides a musical interpretation of lunar libration, stated in a cello/clarinet duet.

LISTENING MAP

00:00 - 00:10	Solo cello introduces a 2-note theme that is explored throughout the ballet
00:12 - 00:35	Introduce the sound of page turns
00:36	Striking match
00:41 - 00:53	Enter alto voice in duet with cello, representing tidal lock between caused by the orbit and rotation of the moon
01:10	The quickly repeated “you” phrase is introduced by the alto voice, representing both gravity (in general) and angular momentum of the moon
01:38	Clarinet first echos the same “you” phrase
02:32	The “anchored” phrase continues to develop between the alto and clarinet, now in different octaves while the cello continues to develop and lengthen the short musical phrase – signifying the passing of time and the cyclical pattern
02:33 - 03:57	Continue to develop these two phrases within the alto voice, clarinet, and cello trio, including a slow version of the repeated one-note figure (“forever anchored”)
03:58 - 05:47	This musical interlude explores the gentle nodding of the moon (libration), ending with a new form of the repeating one-note phrase and a new word (“love”) bringing in another metaphor for gravity and tidal lock
03:58 - 05:47	Chorus enters to provide additional support and resonance to the trio before introducing the breathing musical phrase at 07:46.

SCIENCE LESSON DETAILS AND MATERIALS LIST

Lesson: Kinesthetic Radial Model of the Solar System:

Overview: Students model the planets in their actual positions around the Sun, incorporate the geometry of viewing parameters from earth and visualize where planets will be seen (if visible) in the night sky on any given date.

Activity Details:

- Subjects: Science, Math
- Grade Levels: 6-12
- Primary Topics: Earth and Space Science
- Time Required: 30 min-1 hour
- Type: Classroom activity, out-of-school activity

Materials:

- Circular piece of wood or particleboard, .05 inches thick and 12 inches in diameter, with a pre-drilled center hole
- Wood dowel, at least 6 inches in length, to fit center hole of round wood panel board
- Circular protractor
- Dark-colored felt-tip permanent marker
- String
- Scrap cardboard
- Half-inch wood beads to represent planets OR printed images of each planet
- Heliocentric longitudes for the planets (search for “planetary heliocentric longitudes” along with current and upcoming year)
- (Optional) wood sphere with a hole for the dowel OR a blank wooden doll head, about 2 inches in diameter
- (Optional) paint

View: “Solar System Size and Distance”:

<https://www.jpl.nasa.gov/edu/teach/activity/kinesthetic-radial-model-of-the-solar-system/>

Full Lesson Plan: <https://www.jpl.nasa.gov/edu/teach/activity/kinesthetic-radial-model-of-the-solar-system/>

SCIENCE LESSON DETAIL AND MATERIALS LIST

Lesson: Modeling the Earth-Moon System

Overview: Using an assortment of playground and toy balls, students will measure diameter, calculate distance and scale, and build a model of the Earth-Moon system.

Activity Details:




- Subjects: Science, Math
- Grade Levels: 6-8
- Primary Topics: Earth, Moon, and Sun
- Time Required: 30 mins- 1 hour
- Type: Classroom activity, out-of-school activity, teachable moments

Materials:

- 2 round balloons (at least 8-inch size, preferably 12-inch size)
- Full-size men's basketball (or a beach ball or other ball about 75 cm in circumference)
- Tennis ball or baseball
- Balls of assorted sizes (marbles, tennis balls, golf balls, table tennis balls, softballs, plastic toy balls, basketballs, soccer balls, volleyballs, etc.) (1 per pair of students)
- Modeling clay (1 piece per pair of students)
- String (1 length per pair of students, up to approximately 750 cm)
- Rulers, meter sticks (2 per pair of students)
- Earth-Moon Model Distance Data Sheet (1 per student)- provided HERE

Full Lesson Plan: <https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-earth-moon-system/>

ADDITIONAL RESOURCES

-  [Basics of Space Flight | Glossary of Terms | NASA](#)
-  [Driving Question Board | Open Sci Ed](#)
{<https://www.openscienced.org/driving-question-board/>}
-  [Question Formulation Technique | The Right Question Institute](#)
{<https://rightquestion.org/what-is-the-qft/>}

MODULE 2

PATTERNS OF THE SUN- EARTH-MOON SYSTEM

Of Gravity and Light, Movement II:
*the Moon orbits Earth and Earth orbits the Sun -- everything is
moving. Always.*

Next Generation Science Standards

MS-ESS1-1

Cyclic Patterns of the Earth-Moon System (lunar phases)

MS-ESS1-2

Develop a model to describe the role of gravity in motions of the Sun-Earth-Moon System



Image from *Of Gravity and Light*, mvmt VI

STUDENTS WILL



**PARTICIPATE IN ARTS INTEGRATED
INTRODUCTORY LESSONS (CREATIVITY)**



**EXPLORE HANDS-ON MODEL-BUILDING
ACTIVITIES (CREATIVITY)**



**DEVELOP RESEARCH QUESTIONS THAT CONNECT
TO THE DRIVING QUESTION (RESEARCH)**



**INVESTIGATE MULTIMEDIA INTRODUCTIONS
WITH MINI-LESSONS (RESEARCH)**



**ACCESS ENRICHMENT RESOURCES FOR FURTHER
SUMMATION AND EXTENSION (RESEARCH)**



**ENGAGE WITH DISCUSSION QUESTION BOARD
AND INDIVIDUAL SCIENCE JOURNALS
THROUGHOUT THE MODULES (FORMATIVE
ASSESSMENT)**



**CREATE, EXPLAIN, AND PRESENT AN ORIGINAL
FINAL ARTWORK AS A CONCEPTUAL MODEL OF
ONE BIG IDEA FROM THIS MODULE
(SUMMATIVE ASSESSMENT)**

STUDENTS WILL USE



COMPUTERS/TABLETS AND THE INTERNET



RESEARCH JOURNAL



A CLASSROOM DRIVING QUESTION BOARD



ARTS AND CRAFTS MATERIALS

BIG IDEAS

A note to educators: These are the primary concepts explored in this module and should guide instruction. Do not begin the module by presenting these concepts. Instead, let students come to these conclusions through investigation, inquiry, discussion, and reflection throughout the inquiry-led module. Once students draw a conclusion – post the corresponding Big Idea in your classroom.

The moonlight we see on Earth is sunlight reflected off the Moon's grayish-white surface. **(SCIENCE)**

Patterns of the apparent motion of the sun and the moon in the sky can be observed, described, and predicted. Lunar phases are one of the patterns that result from orbital motion within the Sun-Earth-Moon. **(SCIENCE)**

Music can act as a model to represent the fundamental principles of gravity – exploring ideas of gravity/repetition, distance/intervallic relationships and silence, and orbit/dynamic changes (getting louder and softer). **(CREATIVITY)**

Music, dance, and visual art can serve as models to better understand lunar phases, libration, and tidal lock while also exploring the physical properties of the moon, itself. **(CREATIVITY)**

The Sun-Earth-Moon System can serve as a metaphor to our social and emotional relationships. **(SOCIAL-EMOTIONAL LEARNING)**

Lunar phases is a predictable phenomenon that marks the progression of time, similar to early clocks and calendars. **(SYSTEMS)**

ARTFUL INTRODUCTION



creativity

A note to educators: This exercise immerses students in the scientific concept through creativity, critical thinking, and embodiment as a form of investigation and research. This introduction should be relatively brief, provide a foundation for exploration, plant seeds for curiosity, and align the classroom in a social-emotional learning community.

Examine

the title of this movement. What does “...everything is moving. Always.” mean to you? Think about a constant tick or rhythm of a machine, engine, or clock. Listen to your own heartbeat – what does the consistent rhythm mean to you?

Explore

Close your eyes. Breathe in (count 1-2-3). Breathe out (count 1-2-3). Gently tap the tip of your forefinger on your forehead or cheekbone. Keep gently tapping in a steady constant rhythm while breathing deeply. Grow to two, three, all ten fingers to gently tap on your forehead or cheekbones or eyebrows while you continue to breathe deeply (after 60 seconds, invite the class to stop). In addition to the constant tapping, how else is your body constantly moving? How did this exercise feel? What did you notice? – did it feel anxious or calming? Why? Student Research Journal.

Listen and Watch



Of Gravity and Light, Movement II: the Moon orbits Earth and Earth orbits the Sun -- everything is moving. Always 

Respond



Close your eyes. Breathe in (count 1-2-3). Breathe out (count 1-2-3). Gently tap the tip of your forefinger on your forehead or cheekbone. Keep gently tapping in a steady constant rhythm while breathing deeply. Grow to two, three, all ten fingers to gently tap on your forehead or cheekbones or eyebrows while you continue to breathe deeply (after 60 seconds, invite the class to stop). In addition to the constant tapping, how else is your body constantly moving? How did this exercise feel? What did you notice? – did it feel anxious or calming? Why?

QUESTION



A note to educators: This lesson uses the **Driving Question Board** to help students track their learning, prompt classroom discussion, and develop sub-questions questions. The overarching question is a “sneaky” entry point to the Big Ideas, intending to spark interest and curiosity.



DRIVING QUESTION:

WHY DOES THE MOON APPEAR TO CHANGE SHAPE?

Create a prediction for the question: *Why does the moon appear to change shape?*

THINK: Write the question and individual predictions in their Research Journal.

PAIR: Share Share questions and responses with a partner or in small groups. What do you notice? What do you think you know? What seems completely unknown? What are you curious about?

SHARE: Contribute to the classroom *Driving Question Board* in a teacher-facilitated discussion or independently.

Sub-questions may organically come from students. Teachers may wish to facilitate this lesson by volunteering sub-questions. Examples include:

- What causes the moon to glow in the night sky?
- What causes the lunar phases?
- How are the lunar phases and eclipses related? Are they related?

DO/EXPLORE



MEDIA INVESTIGATION



Students search for clues and information to further their learning while engaging with interactive media to better understand the Sun-Earth-Moon System.



Phases of the Moon, part 1 | PBS/GBH

Explore why the Moon has phases with this first of two interactive lessons that allows students to use simulations and models of the Earth–Sun–Moon system. The lesson includes handouts for students to complete while using multiple simulations that model how the relative positions of the Sun, the Moon, and Earth lead to the cycle of changes in the Moon’s apparent shape.

<https://iowa.pbslearningmedia.org/resource/buac19-68-sci-ess-phasesmoon1/phases-of-the-moon/>



Phases of the Moon, part 2 | PBS/GBH

Explore why the Moon has phases with this second of two interactive lessons that allows students to use simulations and models of the Earth–Sun–Moon system. The lesson includes handouts for students to complete while using multiple simulations that model how the relative positions of the Sun, the Moon, and Earth lead to the cycle of changes in the Moon’s apparent shape.

<https://iowa.pbslearningmedia.org/resource/buac19-68-sci-ess-phasesmoon2/phases-of-the-moon-part-2/>

HANDS-ON LESSONS



Students work in pairs or small groups to build a model of the Earth-Moon System



Moon Phases | NASA

In this activity, students learn about the phases of the moon by acting them out. In 30 minutes, they will act out one complete, 30-day, moon cycle.

<https://www.jpl.nasa.gov/edu/teach/activity/moon-phases/>

DO/EXPLORE



MEDIA EXTENSIONS



Students can access these short media resources for further investigation, deeper understanding, or a homework/prework activity.



Moon in Motion | NASA

Use this resource for additional reinforcement and investigation.

<https://moon.nasa.gov/moon-in-motion/moon-phases/>



Lunar Phases Simulation | NASA

Use this resource to develop and use models to construct an understanding of why the Moon's appearance changes through a cycle of phases as viewed from Earth.

<https://iowa.pbslearningmedia.org/resource/buac19-68-sci-ess-moonphaseint/lunar-phases-simulation/>



Earth's Moon | NASA

Explore lunar phases and lunar eclipses in this multimedia resources.

<https://solarsystem.nasa.gov/moons/earths-moon/lunar-phases-and-eclipses/>

REFLECT



Formative
Assessment

Review the **Driving Question Board** and **Research Journals**.



1. How did your results compare to your predictions? Make any necessary corrections.
2. What new questions do you now have?
3. What did the activities teach you about the moon? about the Sun-Earth-Moon System?
4. What key words are you using to talk about this concept? What questions do you have about key words shared in the Big Ideas?

View Interview | Tom Mattingly describing relationship between dance and music

View Interview | Ilya Vidrin describing partnership between dancers and the role of gravity

View Interview | Sara Nelson and the role of Social-Emotional Learning in creativity and the sciences

APPLY



Listen/Watch (*Of Gravity and Light, Movement II: the Moon orbits Earth and Earth orbits the Sun -- everything is moving. Always*). Video Clip is of Tom Mattingly's choreography and Yu-Wen Wu's video projection, paired with Beau Kenyon's musical score. Think about how you would use sound/music or dance/movement to express one or many principles of gravity.

1. How many instruments do you hear? What images do you see?
2. What instruments would you use? What does the movement look like?
3. Would it be fast or slow? What abstract images would you use?
4. What did you notice about the color, shape, and texture of the moon in Yu-Wen Wu's video projection?
5. How would you describe Tom Mattingly's choreography?



From *Of Gravity and Light, mvmt II*

APPLY



In small groups, partners, or individually, select one specific science concept we explored in this module. Make a plan on how you would represent that scientific idea through music, dance, or video. Feeling stuck?

Use your Research Journal and the Discussion Question Board for ideas



ENVISION

1. Choose one of the Big Ideas (SCIENCE).
2. Brainstorm a list of ways you would represent this Big Idea with music, dance, or visual art.
3. Sketch/Outline 2- 3 ideas and discuss with your group, which one you will decide to create.

PLAN

1. Choose one idea, write 5-7 sentences describing the creative/science project
 - a. What scientific concept will you interpret through art? (be specific)
 - b. What artform(s) will you use?
 - c. Why will you use those specific artforms? What do they represent?
 - d. Include a sketch
2. Who will be responsible for which part of the project?
3. How will you know if the project is “successful”?
4. Consult with your teacher

CREATE, EXPLAIN AND PRESENT

1. Collaborate or work independently to create your final project
2. Present your creative project to the class and explain exactly how it relates to the science of the Big Idea(s) of the Module.

MORE ABOUT

*Of Gravity and Light, Movement II:
the Moon orbits Earth and Earth orbits the Sun -- everything
is moving. Always.*

This scene is for soprano, alto, baritone, Bb clarinet, horn, violin, viola, cello, and piano. The 3.5 minute movement explores the interconnected systems of planets that are held together by gravity. Rather than exploring and expressing the varying gravitational pull experienced by different planets, this piece captures the constant force of gravity that sets the clockwork of our solar system in motion. It was also interesting to explore the way ancient civilizations used their observation of the moon phases as a means to mark and calendar the passing of time – a phenomena explored in Module 2.

The repeated figure, first stated in the string trio at the beginning of the piece, is passed through entire ensemble before returning back to the strings at the end. You may hear instruments (like the horn and clarinet) enter and leave the ensemble to express the passing of time – that we are moving forward, growing, and changing while constantly moving in orbital patterns. The quirky quips and interjections by the piano and clarinet intend to also comment on the unpredictable nature of our galaxy as well as our experiences on Earth – that although we are all tied together by gravity, experiencing a now predictable passage of time, surprises and tiny treasures still pop up in isolated or connected ways.

Still image from Yu-Wen Wu's video projection from **Of Gravity and Light, mvmt II**



LISTENING MAP

- 00:00 - 00:31 Repeated figure is explored by the string trio, first pizzicato then arco
- 00:17 Piano theme begins to interject into the repeated texture
- 00:32 Horn takes over the repeated figure - though it is the same note, the round timbre of the horn provides a new sonic texture
- 00:47 Clarinet in a very high register enters - still same pitch but 2 octaves above, giving the repetition new energy and character
- 00:51 - 02:31 Development of the theme as the violin, viola, cello, clarinet, horn, and piano have a "conversation" together
- 02:33 Soprano marks the entrance of vocalists (followed shortly after by the alto and baritone at 2:44), signifying either civilization's role and use of gravity and orbital cycles to move toward progress and planning
- 03:11 - 03:21 Slowly fade as the repeated figure is passed from solo violin to solo clarinet to solo cello

SCIENCE LESSON DETAIL AND MATERIALS LIST

Lesson: Moon Phases

Overview: Students learn about the phases of the moon by acting them out. In 30 minutes, they will act out one complete, 30-day, moon cycle.

Activity Details:

- Subjects: Science, Math
- Grade Level: 1-6
- Primary Topic: Astronomy
- Time Required: 30 mins-1 hour
- Types: Classroom activity, demonstration, out-of-school activity

Materials:




- Pencil (one per student)
- White Styrofoam ball (one per student)- 5 centimeters or larger
- Light source, such as a lamp (shade removed) with a bright, clear, incandescent bulb (100 watts or higher)

Full Lesson Plan: <https://www.jpl.nasa.gov/edu/teach/activity/moon-phases>

Lesson: Moon in Motion:

Lesson overview, activity details, and materials not provided, but here is a link to the overall lesson to learn more: <https://moon.nasa.gov/moon-in-motion/moon-phases/>

ADDITIONAL RESOURCES

-  [Basics of Space Flight | Glossary of Terms | NASA](#)
-  [Driving Question Board | Open Sci Ed](#)
{<https://www.openscienced.org/driving-question-board/>}
-  [Question Formulation Technique | The Right Question Institute](#)
{<https://rightquestion.org/what-is-the-qft/>}

MODULE 3 PATTERNS OF THE EARTH AND ITS MOON

*Of Gravity and Light, Movement IV:
temporarily obscured, by passing into the shadow of another body*

Next Generation Science Standards

MS-ESS1-1

Cyclic Patterns of the Earth-Moon System (eclipses of the sun and moon)

MS-ESS1-2

Develop a model to describe the role of gravity in motions of the Sun-Earth-Moon System



Image from *Of Gravity and Light*, mvmt VI

STUDENTS WILL



PARTICIPATE IN ARTS INTEGRATED INTRODUCTORY LESSONS (CREATIVITY)



EXPLORE HANDS-ON MODEL-BUILDING ACTIVITIES (CREATIVITY)



DEVELOP RESEARCH QUESTIONS THAT CONNECT TO THE DRIVING QUESTION (RESEARCH)



INVESTIGATE MULTIMEDIA INTRODUCTIONS WITH MINI-LESSONS (RESEARCH)



ACCESS ENRICHMENT RESOURCES FOR FURTHER SUMMATION AND EXTENSION (RESEARCH)



ENGAGE WITH DISCUSSION QUESTION BOARD AND INDIVIDUAL SCIENCE JOURNALS THROUGHOUT THE MODULES (FORMATIVE ASSESSMENT)



CREATE, EXPLAIN, AND PRESENT AN ORIGINAL FINAL ARTWORK AS A CONCEPTUAL MODEL OF ONE BIG IDEA FROM THIS MODULE (SUMMATIVE ASSESSMENT)

STUDENTS WILL USE



COMPUTERS/TABLETS AND THE INTERNET



RESEARCH JOURNAL



A CLASSROOM DRIVING QUESTION BOARD



ARTS AND CRAFTS MATERIALS

BIG IDEAS

A note to educators: These are the primary concepts explored in this module and should guide instruction. Do not begin the module by presenting these concepts. Instead, let students come to these conclusions through investigation, inquiry, discussion, and reflection throughout the inquiry-led module. Once students draw a conclusion – post the corresponding Big Idea in your classroom.

An eclipse is an event that occurs when an astronomical object or spacecraft is temporarily obscured, by passing into the shadow of another body or by having another body pass between it and the viewer. (**SCIENCE**)

The Sun-Earth-Moon System is an interdependent system made of the three bodies that create a series of patterns. Earth's Moon orbits the Earth, the Earth orbits the Sun. An outcome of this system is solar and lunar eclipse – witnessed from our vantage point on Earth. (**SCIENCE**)

Music can be composed to represent this phenomena, exploring ideas of synchronicity/unison, orbit/counterpoint, and eclipse/silence. (**CREATIVITY**)

Music, dance, and video can capture the emotional response to witnessing a solar eclipse – how might we feel in the anticipation of viewing an eclipse? How might we feel after sharing this experience with others? (**SOCIAL-EMOTIONAL LEARNING**)

The Sun-Earth-Moon System can serve as a metaphor to our social and emotional relationships. (**SOCIAL-EMOTIONAL LEARNING**)

Analogous to the Sun-Earth-Moon System, *Of Gravity and Light* is comprised of a 3-Part System: Music, Dance, and Video Projection. Each artistic discipline is made up of its own complex system of parts that, together, become three interdependent bodies on stage. (**SYSTEMS**)

ARTFUL INTRODUCTION



A note to educators: This exercise immerses students in the scientific concept through creativity, critical thinking, and embodiment as a form of investigation and research. This introduction should be relatively brief, provide a foundation for exploration, plant seeds for curiosity, and align the classroom in a social-emotional learning community.

Examine

the title of this movement. What does “temporarily obscured by passing into the shadow of another body” mean to you? Imagine knowing something or someone who is always present – something or someone who gives you comfort, joy, security, and you are blocked from seeing them for a moment. What/Who do you imagine? How does it feel to lose sight of it/them? How might you represent that feeling in a sound or movement? What do you think this specific movement is about? Why do you think that?

Explore

eclipses based on what you know (or think you know) about the motion of our Sun-Earth-Moon System and how eclipses are caused. In groups of 3, assign roles of the Sun, the Earth, and the Moon. Together, plan, practice, and present an embodied interpretation of a solar or lunar eclipse. Groups may also wish to explore eclipses as a metaphor – what does an eclipse mean to you? Perfect alignment? Mystery? Loneliness? Frustration?

Listen and Watch



Of Gravity and Light, Movement VI: temporarily obscured, by passing into the shadow of another body 

Respond



The composer, video artist, and choreographer explore many different ways to represent and explore an eclipse. This piece explores our emotional response to a scientific event as well as the science itself – when in the music do you think that our view is “temporarily obscured”? Why do you think that? Why do you think the composer chose to have musicians represent it in that way? How many “eclipses” do you see and hear

ARTFUL INTRODUCTION



Study the images below, what is happening in the images on the left? Why do you think that? What does it mean to witness an event like this with others? Would you prefer to witness it together or alone? There is no correct answer – what do you think your preference would be? Why? Describe the images on the right. What is happening? What feelings might you have if you were there to see this? How would you represent this musically? Would you focus on the scientific explanation of an eclipse? The community? Your own feelings?



An annular solar eclipse viewed from Hofuf, Saudi Arabia, in 2019. Hamad I Mohammed/Reuters



A partial solar eclipse seen last year from Karachi, Pakistan. Rehan Khan/EPA, via Shutterstock



Do not view the eclipse without proper eyewear, like these eclipse-chasers in Kathmandu, Nepal, last June. Prakash Mathema/Agence France-Presse — Getty Images



☞ Sunday's annular eclipse coincides with northern hemisphere's summer solstice, when Earth's north pole is tilted most directly toward the sun. Photograph: Ferdinandh Cabrera/AFP via Getty Images

QUESTION



A note to educators: This lesson uses the Driving Question Board to help students track their learning, prompt classroom discussion, and develop sub-questions questions. The overarching question is a “sneaky” entry point to the Big Ideas, intending to spark interest and curiosity.



DRIVING QUESTION:

WHY DOES THE MOON APPEAR TO CHANGE SHAPE?

Create a prediction for the question: *Why does the moon sometimes appear red?*

THINK: Write the question and individual predictions in their **Research Journal**.

PAIR: Share questions and responses with a partner or in small groups. What do you notice? What do you think you know? What seems completely unknown? What are you curious about?

SHARE: Contribute to the classroom *Driving Question Board* in a teacher-facilitated discussion or independently.

Sub-questions may organically come from students. Teachers may wish to facilitate this lesson by volunteering sub-questions. Examples include:

- Do lunar eclipses and solar eclipses happen at the same frequency?
- What effect do eclipses have on Earth’s nature/wildlife?
- Why doesn’t an eclipse happen every month?

DO/EXPLORE



MEDIA INVESTIGATION



Students search for clues and information to further their learning while engaging with interactive media to better understand the Sun-Earth-Moon System.



Phases of a Total Solar Eclipse | PBS/GBH

Experience what it is like to see a total solar eclipse. Photographs show how the Sun appears during various phases of a solar eclipse, and a video captures the reactions of people during totality. Use this resource to visualize a total solar eclipse and to relate science concepts to real-life experiences.

<https://iowa.pbslearningmedia.org/resource/buac18-sci-ess-tsephases/phases-of-a-total-solar-eclipse/>

INTERACTIVE LESSON



Students work in pairs or small groups to build a model of the Earth-Moon System.



Modeling the Earth-Moon System | PBS/GBH

Investigate how the orbits and relative positions of the Moon, the Sun, and Earth produce eclipses using this interactive lesson. Students will work with a variety of models of the Earth-Sun-Moon system to understand the mechanics of lunar and solar eclipses and explain why they are rare.

<https://iowa.pbslearningmedia.org/resource/buac18-68-sci-ess-noeclipsemonthly-il/why-isnt-there-an-eclipse-every-month/>

MEDIA EXTENSIONS



Students can access these short media resources for further investigation, deeper understanding, or a homework/prework activity.



Rotations in Space | PBS

Explore lunar phases and lunar eclipses in this multimedia resources.

<https://solarsystem.nasa.gov/moons/earths-moon/lunar-phases-and-eclipses/>



Moon in motion: Lunar Eclipse | NASA

Explore lunar phases and lunar eclipses in this multimedia resources.

<https://moon.nasa.gov/moon-in-motion/eclipses/>

REFLECT



Formative
Assessment

Review the **Driving Question Board** and **Research Journals**.



1. How did your results compare to your predictions? Make any necessary corrections.
2. What new questions do you now have?
3. What did the activities teach you about the moon? about the Sun-Earth-Moon System?
4. What key words are you using to talk about this concept? What questions do you have about key words shared in the Big Ideas?

View Interview | Yu-Wen Wu describes the experience of capturing an eclipse with her video equipment

View Interview | Merritt Moore describing the science of an eclipse and what that means to her

View Interview | Julie Fox Henson, Jonathan Sturm, Julie Sturm describe how they play as an ensemble

APPLY



Listen/Watch (*Of Gravity and Light, Movement VI: temporarily obscured, by passing into the shadow of another body*). Video Clip is of Yu-Wen Wu's video installation, paired with Beau Kenyon's musical score. Think about how you would use sound/music to represent an eclipse.

1. How many instruments do you hear? Why do you think the composer chose to write for three similarly-sounding instruments to represent the Sun-Earth-Moon System? What images do you see?
2. What instruments would you use? What imagery?
3. What abstract images would you use?
4. Would you use silence or something else to signify the eclipse?



Image from *Of Gravity and Light*, mvmt IV

APPLY



In small groups, partners, or individually, select one specific science concept we explored in this module. Make a plan on how you would represent that scientific idea through music, dance, or video. Feeling stuck?

Use your **Research Journal** and the **Discussion Question Board** for ideas



ENVISION

1. Choose one of the Big Ideas (SCIENCE).
2. Brainstorm a list of ways you would represent this Big Idea with music, dance, or visual art.
3. Sketch/Outline 2- 3 ideas and discuss with your group, which one you will decide to create.

PLAN

1. Choose one idea, write 5-7 sentences describing the creative/science project
 - a. What scientific concept will you interpret through art? (be specific)
 - b. What artform(s) will you use?
 - c. Why will you use those specific artforms? What do they represent?
 - d. Include a sketch
2. Who will be responsible for which part of the project?
3. How will you know if the project is “successful”?
4. Consult with your teacher

CREATE, EXPLAIN AND PRESENT

1. Collaborate or work independently to create your final project
2. Present your creative project to the class and explain exactly how it relates to the science of the Big Idea(s) of the Module.

MORE ABOUT

Of Gravity and Light, Movement IV: temporarily obscured by passing into the shadow of another body

This scene is for string trio: 2 violins (who double on viola) and 1 cello. The 9-minute movement represents the orbital relationship between the Sun, Earth, and Moon – each of the three instruments explore similar musical themes and ideas while they “orbit” around each other. This musical figure was intended to feel buoyant, weightless, and still moving forward. You may notice that at times, the cello and viola play in octave unison or the violin and viola play in unison. This signifies the sometimes synchronous rotational relationship. As the piece approaches 5 minutes, the musical tension begins to mount and the rhythm stretches into a longer sustain. About two-thirds into the piece, the tension increases along with the dynamic (volume) until the violin cuts through the texture and leads toward the eclipse (silence). The climax of the piece is the silence – it is the moment when our view of the Sun is gone, when everything we hear on Earth stops for a brief moment. What begins after is led by the cello. It is a sort of coda or reflection of what just happened – understanding that we all witnessed this phenomena together, and that just for a moment, we experienced an otherworldly, celestial phenomena.

Still image from Yu-Wen Wu's video projection from **Of Gravity and Light, mvmt VI**



LISTENING MAP

00:00 - 00:34	2 violas playing sustained notes, together they play a single melodic line
00:35	Cello enters on an accented note to complete the melodic texture and counter melody
01:17	a new figure is introduced that moves at a quicker rhythm - generating momentum into
02:11	Brief octave unison between cello and viola, signifying that moment when the Sun and Moon are rotating in perfect synchronicity
03:00 - 3:27	A series of octave unison between viola and cello, in the momentum-building figure
3:28	A new higher register for the viola while continuing to explore the orbital relationships between the three bodies
4:33	A brief solo cello in a high register to move toward the climax section - a quiet, floaty moment to near foreshadow the solo violin
05:30 - 05:45	Tension increases along with the dynamic (volume)
05:45	Violin cuts through the texture to add a different level of tension - that moment of "it's about to happen" kind of feeling
05:51	Eclipse (silence), it is the moment when our view of the Sun is obstructed
05:55	Beginning of Coda or reflection of what just happened - understanding that we all witnessed something remarkable together, that just for a moment, we experienced an otherworldly, celestial phenomena
06:50	Introduction of the violin harmonics figure (high ascending notes) to lead our perspectives from self-reflective to expansive reflection about the mysteries of the galaxy
7:28 - 08:46	Chorus enters to provide additional support and resonance to the trio before introducing the breathing musical phrase at 07:46.

SCIENCE LESSON DETAIL AND MATERIALS LIST

Lesson: When do Lunar Eclipses Happen?

Overview: In this activity, students use a paper plate to build a model that shows why lunar eclipses don't happen during every full moon.

Activity Details




- Subjects: Science, Math
- Grade Levels: 4-8
- Primary Topic: Solar System
- Time Required: Less than 30 mins
- Types: Classroom activity

Materials:

- Paper plate, take-out container, or another flat surface with raised edges (thick material recommended), 1 per student or group
- Pencil, pen, or marking pen
- Scissors
- Small ball, approximately 3-5 centimeters (1-2 inches) in diameter, or another object to represent the Sun, 1 per student or group
- (Optional) Jar, lid, or another round object that can be used to trace out a circle

Full Lesson Plan: <https://www.jpl.nasa.gov/edu/teach/activity/when-do-lunar-eclipses-happen>

ADDITIONAL RESOURCES

-  [Basics of Space Flight | Glossary of Terms | NASA](#)
-  [Driving Question Board | Open Sci Ed](#)
{<https://www.openscienced.org/driving-question-board/>}
-  [Question Formulation Technique | The Right Question Institute](#)
{<https://rightquestion.org/what-is-the-qft/>}

MODULE 4 PROPERTIES OF THE SOLAR SYSTEM

*Of Gravity and Light, Movement VII:
believed light is a particle and a wave*

Next Generation Science Standards

MS-ESS1-2

Develop a model to describe the role of gravity in motions within the solar system

MS-ESS1-3

Interpret data to determine scale properties of objects in our solar system (determine similarities and differences among planets, including surface features and orbital radius)



Image from **Of Gravity and Light, mvmt VII**

STUDENTS WILL



PARTICIPATE IN ARTS INTEGRATED INTRODUCTORY LESSONS (CREATIVITY)



EXPLORE HANDS-ON MODEL-BUILDING ACTIVITIES (CREATIVITY)



EXPLORE INTERACTIVE MEDIA ACTIVITIES (CREATIVITY)



DEVELOP RESEARCH QUESTIONS THAT CONNECT TO THE DRIVING QUESTION (RESEARCH)



INVESTIGATE MULTIMEDIA INTRODUCTIONS WITH MINI-LESSONS (RESEARCH)



ACCESS ENRICHMENT RESOURCES FOR FURTHER SUMMATION AND EXTENSION (RESEARCH)



ENGAGE WITH DISCUSSION QUESTION BOARD AND INDIVIDUAL SCIENCE JOURNALS THROUGHOUT THE MODULES (FORMATIVE ASSESSMENT)



CREATE, EXPLAIN, AND PRESENT AN ORIGINAL FINAL ARTWORK AS A CONCEPTUAL MODEL OF ONE BIG IDEA FROM THIS MODULE (SUMMATIVE ASSESSMENT)

STUDENTS WILL USE



COMPUTERS/TABLETS AND THE INTERNET



RESEARCH JOURNAL



A CLASSROOM DRIVING QUESTION BOARD



ARTS AND CRAFTS MATERIALS

BIG IDEAS

A note to educators: These are the primary concepts explored in this module and should guide instruction. Do not begin the module by presenting these concepts. Instead, let students come to these conclusions through investigation, inquiry, discussion, and reflection throughout the inquiry-led module. Once students draw a conclusion – post the corresponding Big Idea in your classroom.

Gravity is the force that creates the shape and motion in our solar system. **(SCIENCE)**

Each planet's distance from and relationship to the sun contributes to its physical characteristics. **(SCIENCE)**

Like the Sun-Earth-Moon System, the Solar System abides by the laws of gravity and its relationship to mass and distance. **(SCIENCE)**

Art and Creativity can represent seemingly opposing concepts that are not mutually exclusive (i.e., light is a particle and a wave) **(CREATIVITY)**

Like the interdependent nature of the Solar System, Art frequently requires a complex system of parts and people who work together **(CREATIVITY)**

Our Solar System can be a metaphor for our internal emotional responses as well as how we relate within man-made social systems. **(SOCIAL-EMOTIONAL LEARNING)**

Analogous to the Role and Principles of Gravity, *Of Gravity and Light* is held together by a central theme and concept/gravity which then comes to life in an interdependent system of parts – i.e., people, performers, and artists who orbit/work together in different levels of frequency/importance. **(SYSTEMS)**

ARTFUL INTRODUCTION



A note to educators: This exercise immerses students in the scientific concept through creativity, critical thinking, and embodiment as a form of investigation and research. This introduction should be relatively brief, provide a foundation for exploration, plant seeds for curiosity, and align the classroom in a social-emotional learning community.

Examine

the title of this movement. What does “*believed light is both a particle and a wave*” mean to you? What is the importance of the word “believe”? How is believing in something different from “knowing”? – Why is this word important when talking about art? How we talk to others about new ideas? What do you think this specific movement is about? Why do you think that? How is the word “believe” important for how we talk about science?

Explore

the interconnected and interdependent relationships of our Solar System. (variation of a group warm-up activity from *Theatre of the Oppressed*, pg. 49). One participant goes in the center and imagines himself to be a part in a big complex machine. He does a repetitive motion and creates the sound which goes with it. Everyone watches. Another participant goes in and connects themselves to the first person, in a way that shows a connection between the two parts of the machine they are portraying. Then another participant joins them and the machine gets bigger till everyone is playing a part and vocalizing a sound with their motion. Participants can join in whichever part of the machine they feel. Motions and sounds are repetitive as the “machine” grows and becomes increasingly more complex. Now that the machine is built and physically interconnected, invite the class to freeze and slowly move to a different, isolated space in the classroom. Stand, sit, or crouch in the same position they were in (when they were physically connected). One-by-one, invite students to restart their motion and sound and observe how others are moving and sounding. Their motions and sounds are interconnected even with space separating their bodies.

ARTFUL INTRODUCTION



Listen

Of Gravity and Light, Movement VII believed light is both a particle and a wave).



Respond

This piece explores light – light from the sun and the sun’s characteristics as well as the light that travels to Earth and how it shapes our ability to thrive. What aspects of the music sound like light particles? Which aspects act as waves? **Compare** this to the video – do you see particles? How do these two elements (video and music) relate to the dance?

QUESTION



A note to educators: This lesson uses the Driving Question Board to help students track their learning, prompt classroom discussion, and develop sub-questions questions. The overarching question is a “sneaky” entry point to the Big Ideas, intending to spark interest and curiosity.



DRIVING QUESTION:

ARE THERE ECLIPSES AND LUNAR PHASES ON EVERY PLANET?

Create a prediction for the question: *Why does the moon sometimes appear red?*

THINK: Write the question and individual predictions in their **Research Journal**.

PAIR: Share questions and responses with a partner or in small groups. What do you notice? What do you think you know? What seems completely unknown? What are you curious about?

SHARE: Contribute to the classroom *Driving Question Board* in a teacher-facilitated discussion or independently.

Sub-questions may organically come from students. Teachers may wish to facilitate this lesson by volunteering sub-questions. Examples include:

- What role does the sun have in defining characteristics of each planet?
- Is there a relationship between each planet’s moon and the sun?
- Are all planets the same size? Shape? Distance apart?
- How do their orbital radii compare?

DO/EXPLORE



MEDIA INVESTIGATION



Students search for clues and information to further their learning while engaging with interactive media to better understand the Sun-Earth-Moon System.



To Scale: The Solar System | PBS

Observe a team as they build an accurate scale model of the solar system on a dry lakebed in Nevada in this video from Wylie Overstreet and Alex Gorosh. Use this resource to visualize the abstract concept of the size and scale of the solar system and to develop and use models.

<https://iowa.pbslearningmedia.org/resource/buac18-68-sci-ess-toscalesolarsystem/to-scale-the-solar-system/>



Measuring Distance in the Solar System | NASA Planetary Science

Explore how astronomers and scientists use astronomical units to measure distances in the solar system in this video adapted from NASA.

<https://iowa.pbslearningmedia.org/resource/npls13.sci.ess.eiu.scaling/measuring-distance-in-the-solar-system-nasa-planetary-sciences/>

INTERACTIVE LESSON



Students work in pairs or small groups to build a model of the Earth-Moon System.



Solar System Explorer | PBS/GBH

Visualize the solar system (including the size of objects, motions, surface features, and distances) with this digital model.

<https://iowa.pbslearningmedia.org/resource/buac20-sci-ess-wwt-solarsystemexplorer/solar-system-explorer/>

DO/EXPLORE



HANDS-ON LESSON



Students work in pairs or small groups to build a model of the Earth-Moon System.



Modeling the Earth-Moon System | NASA JPL

This activity builds on Module 1, when students created a scaled model of the Earth-moon-sun system. Using the same scale as before, students will model the entire solar system.

<https://www.jpl.nasa.gov/edu/learn/project/make-a-scale-solar-system/>

MEDIA EXTENSIONS



Students can access these short media resources for further investigation, deeper understanding, or a homework/prework activity.



Astronomical Units Measure Large Distances | PBS

<https://iowa.pbslearningmedia.org/resource/buac68-sci-ilastrounits/astronomical-units-measure-large-distances/>

Solar System Size and Distance | NASA

<https://www.youtube.com/watch?v=DMZ5WFRbSTc>

PBS LearningMedia Solar System to Scale | PBS

<https://iowa.pbslearningmedia.org/resource/buac18-68-sci-ess-mapmodelss/map-a-model-solar-system/>

Solar System 101 | National Geographic

<https://www.youtube.com/watch?v=libKVRa01L8>

Solar System Scroll | NASA JPL

<https://www.jpl.nasa.gov/edu/teach/activity/solar-system-scroll/>

REFLECT



Formative
Assessment

Review the **Driving Question Board** and **Research Journals**.



1. How did your results compare to your predictions? Make any necessary corrections.
2. What new questions do you now have?
3. What did the activities teach you about the moon? about the Sun-Earth-Moon System?
4. What key words are you using to talk about this concept? What questions do you have about key words shared in the Big Ideas?

View Interview | Mariel Pettee discussing the relationship between art and science

View Interview | Tim McMillin discussing the role of the conductor with musicians

View Interview | NASA Scientist discussing the solar system

APPLY



Listen/Watch (*Of Gravity and Light, Movement VII: believed light is both a particle and a wave*). Video Clip is of Yu-Wen Wu's video installation, paired with Beau Kenyon's musical score, and Tom Mattingly's choreography. Think about how you would use sound/music to represent a specific characteristic of our Solar System.

1. What kind of sounds do you hear? What images do you see?
2. What kind of feeling words would you use to describe this piece?
3. What abstract images would you use?



Image from **Of Gravity and Light, mvmt VIII**

APPLY



In small groups, partners, or individually, select one specific science concept we explored in this module. Make a plan on how you would represent that scientific idea through music, dance, or video. Feeling stuck?

Use your **Research Journal** and the **Discussion Question Board** for ideas



ENVISION

1. Choose one of the Big Ideas (SCIENCE).
2. Brainstorm a list of ways you would represent this Big Idea with music, dance, or visual art.
3. Sketch/Outline 2- 3 ideas and discuss with your group, which one you will decide to create.

PLAN

1. Choose one idea, write 5-7 sentences describing the creative/science project
 - a. What scientific concept will you interpret through art? (be specific)
 - b. What artform(s) will you use?
 - c. Why will you use those specific artforms? What do they represent?
 - d. Include a sketch
2. Who will be responsible for which part of the project?
3. How will you know if the project is “successful”?
4. Consult with your teacher

CREATE, EXPLAIN AND PRESENT

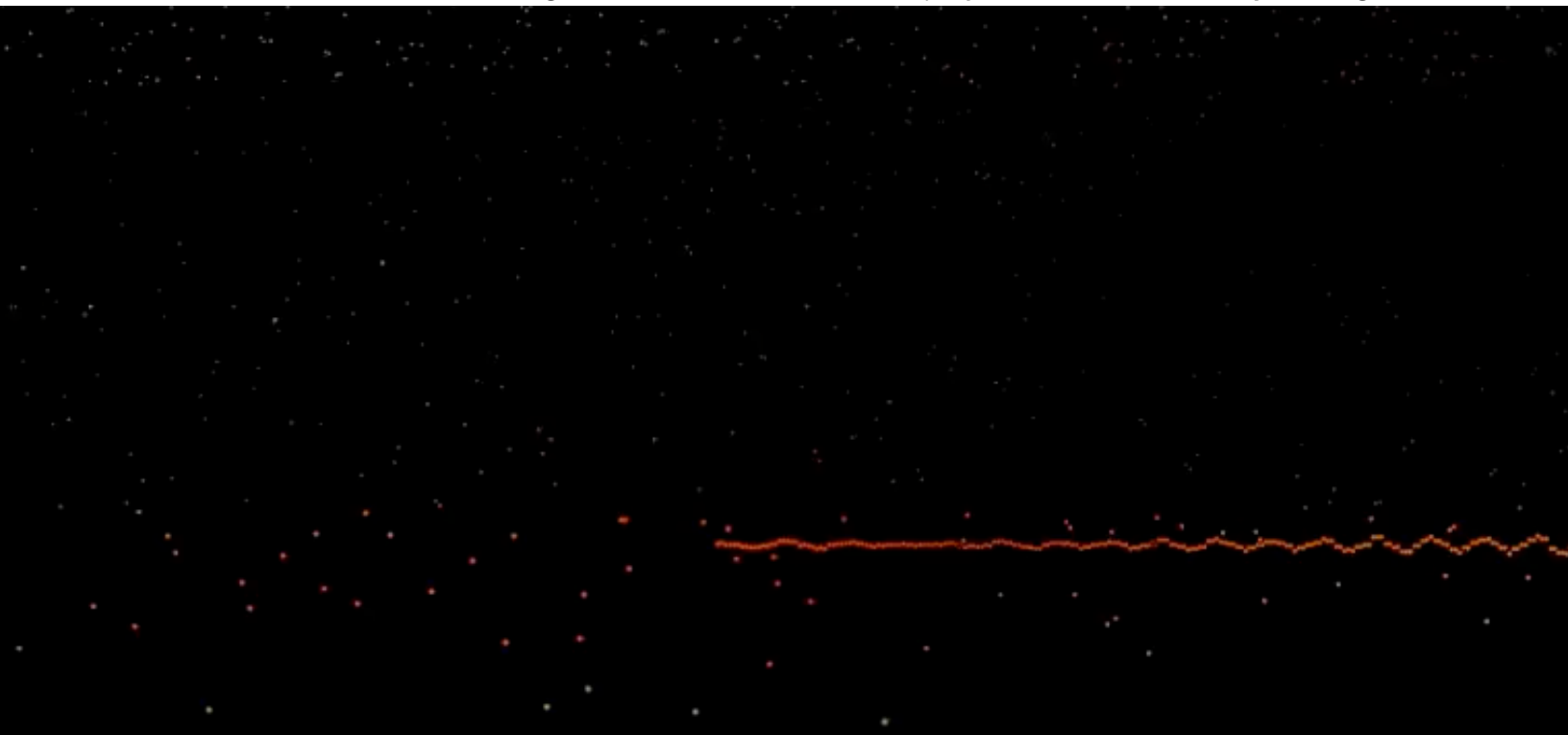
1. Collaborate or work independently to create your final project
2. Present your creative project to the class and explain exactly how it relates to the science of the Big Idea(s) of the Module.

MORE ABOUT

Of Gravity and Light, Movement VII: believed light is both a particle and a wave

This scene is for percussion, clarinet, horn, voice and electronics. Unlike other movements, which feature live musical performances of traditionally notated music, this piece is built from recorded rhythms and instrumental sounds. Short musical phrases are expanded, layered, and produced through music production technology. There are two primary musical themes, representing the two scientific theories that light is both particle and wave – the driving marcato rhythm (percussion) is light as particle and the sound collage of horn, clarinet, and voice is light as wave. The two themes are tethered together and orbit each other – creating a continuum created by gravity and motion. On its smallest level, this movement creates a model of the properties of light and its relationship to gravity; on its most macro level, the music is a model of the sun and its relationship with gravity.

Still image from Yu-Wen Wu's video projection from *Of Gravity and Light*, mvmt VIII



LISTENING MAP

- 00:00 - 00:24 Duo between two percussionists sets up the “light as particle” theme
- 00:00 - 00:25 Clarinet enters on an unstable sound to establish the “light as wave” theme
- 00:47 Introduction of the single repeated note motif that appears throughout the ballet and represents the relationship between gravity and orbit
- 00:51 Example of sound effect created by manipulating recorded musical sound through inversion

SCIENCE LESSON DETAIL AND MATERIALS LIST

Lesson: Make a Scale Solar System

Overview: In this activity, students use scale, proportion, and/or ratios to develop a scale solar system calculator. Using spreadsheet software, students will determine the size of and/or distances between planets on a solar system model that fits on a playground.

Activity Details:

- Subjects: Math, Technology
- Grade Levels: 5-12
- Primary Topic: Earth and Space Science
- Time Required: 30 mins-1 hour
- Types: Classroom activity

Materials:




- Example not-to-scale images of the solar system
- Computer or mobile device
- Spreadsheet software (Excel, Sheets, etc.)
- Distance markers (cones, ground stakes, etc.)
- Paper
- Pencil, pen and/or colored pencils
- Ruler with centimeter markings
- Measuring tape
- Solar System Sizes and Distances reference guide, provided [HERE](#)
- Scale Distance Spreadsheet- can be provided from full lesson plan URL
- Scale Size Spreadsheet- can be provided from full lesson plan URL
- Scale Size and Distance spreadsheet- can be provided from full lesson plan URL

View: “Solar System Size and Distance”:

<https://www.jpl.nasa.gov/edu/teach/activity/kinesthetic-radial-model-of-the-solar-system/>

Full Lesson Plan: <https://www.jpl.nasa.gov/edu/teach/activity/create-a-solar-system-scale-model-with-spreadsheets/>

ADDITIONAL RESOURCES

-  [Basics of Space Flight | Glossary of Terms | NASA](#)
-  [Driving Question Board | Open Sci Ed](#)
{<https://www.openscienced.org/driving-question-board/>}
-  [Question Formulation Technique | The Right Question Institute](#)
{<https://rightquestion.org/what-is-the-qft/>}