Stackable Instructionally-embedded Portable Science (SIPS) Assessments Project

Grade 8 Science

Unit 2 Instructional Framework

Gravity and Motion of Objects in the Solar System

June 2023

The SIPS Grade 8 Science Unit 2 Instructional Framework: Gravity and Motion of Objects in the Solar System was developed with funding from the U.S. Department of Education under the Competitive Grants for State Assessments Program, CFDA 84.368A. The contents of this paper do not represent the policy of the U.S. Department of Education, and no assumption of endorsement by the Federal government should be made.

Table of Contents

Science
Grade: 8 Unit: 2
42 days of instruction

Unit 2 Overview

Storyline Synopsis:

This unit consists of three segments, each engaging students in multiple science and engineering practices and in the application of crosscutting concepts as students make sense of the key disciplinary ideas of the universe and its stars, Earth and the solar system, and underlying gravitational forces that explain the variety of interactions observed.

- **Instructional Segment 1:** By engaging in the practices of analyzing and interpreting data, developing and using models, and constructing and presenting arguments using evidence, students learn that, regardless of mass, gravitational forces are always attractive. They also learn how gravity affects objects of varying masses and/or how this can be used as evidence for their arguments about the connections between gravitational forces and orbital motion. Students begin the unit by exploring an anchor phenomenon that is based on a shared class experience of viewing a video that introduces the James Webb Space Telescope (JWST) to explore the questions, "What forces make it possible for the JWST to move as it did in the video? and "Why can't JWST move in a straight-line path after launch?" This leads to students researching and reviewing information from various sources to address these questions and to identify information to support a claim related to gravitational forces acting on JWST. Additional data related to the relative masses of objects and the magnitudes and interactions of gravitational forces is analyzed and interpreted to help students understand how changes in masses affect the size of the gravitational forces. Students then develop a "consensus" model and create short explanations of how the model shows the relationship between mass and gravitational force. Information about gravitational forces on a human scale is gathered and evaluated and then students conduct two virtual experiments to collect data related to gravitational forces on the human scale and planetary scale. The segment culminates with students researching how scientists use the relationships between masses of planetary objects and orbital motion, the bending of light by gravity, and other methods to discover the location of exoplanets throughout our galaxy.
- **Instructional Segment 2:** By engaging in the practices of developing and using models, analyzing and interpreting data, obtaining, evaluating, and communicating information, and constructing arguments and explanations using evidence, students learn that cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons can be observed, described, and predicted and that analysis and interpretation of data can be used to determine the scale properties of objects in the solar system. Students begin the segment by constructing a model of the solar system based on their current understanding and use it to attempt to explain phases, seasons, and eclipses. Students collect astronomical data using Stellarium – a tool to observe the position of the sun and moon on different days of the year to gather data to revise their model to better explain lunar phases and eclipses. Students explore climatological data and daylight hours, using this data to revise their model to better explain seasons. Finally, students compare their explanations to the "field" by researching other models, identifying the limitations of their model, and then considering any final modifications to their model.
- **Instructional Segment 3:** By engaging in the practices of developing and using models, obtaining, evaluating, and communicating information, and constructing and presenting arguments, students learn the role of gravity in the motions within galaxies and the solar system. Students begin the segment by brainstorming research questions related to the Milky Way galaxy and then

use provided websites to gain information to answer their questions. Students examine simulations of stellar formation to understand the role of gravity in celestial object formation, observe rotational motion to understand the role of gravity in creating disc-shaped objects which dominate our universe, and conduct additional research on the diversity of celestial objects. Students evaluate the validity and sufficiency of the information and communicate their findings by creating communicative products about their learning for target audiences.

Unit Storyline Framing: How do objects in our solar system move and how do we know they move in these ways? How do gravitational forces between objects with mass govern the evolution and maintenance of large-scale systems in space, such as planetary objects in orbit within the solar system and Earth's place in the universe? How can large space-based telescopes, such as James Webb Space Telescope (JWST), be utilized by scientists to discover previously unobserved formations of the first galaxies, to observe dust clouds where star and planetary systems are formed today, and to see back into the cosmos?

Educators are encouraged to modify/change the anchoring activity and unit storyline framing to meet the diverse needs of their students. Today's understanding of the universe through astronomy is built upon the work of a diverse field of astronomers from around the world over thousands of years. A few valuable resources for the teacher to integrate diverse perspectives into their instruction are:

- Unheard Voices, Part 1: The Astronomy of Many Cultures
  [https://multiverse.ssl.berkeley.edu/Portals/0/Documents/Unheard%20Voices%20Resource%20Guides/Multicultural_Astronomy_updated20160812.pdf?ver=2016-09-14-130655-903]
- Unheard Voices, Part 2: Women in Astronomy
  [https://multiverse.ssl.berkeley.edu/Portals/0/Documents/Unheard%20Voices%20Resource%20Guides/Unheard%20Voices%20Women%202021%20To%20Print.pdf?ver=2021-11-01-103527-957]

Science
Grade: 8 Unit: 2
42 days of instruction

Stage 1 – Desired Results

Overview of Student Learning Outcomes

The Grade 8 Unit 2 Topic Bundle, “**Gravity and Motion of Objects in the Solar System**,” organizes performance expectations with a focus on helping students deepen their knowledge about the force of gravity between objects with mass and its role in keeping planetary objects in orbit within the solar system and about Earth’s place in the universe. In this unit, there are significant overlap and synergy between the disciplinary core ideas (DCI) and crosscutting concepts (CCC) dimensions, where patterns of different scales and proportions are traced throughout the multiple components of a system represented in a model. Similarly, the particular SEPs allow students to analyze and interpret similarities and differences in findings which can provide empirical evidence to support or refute an argument based on a model of a phenomenon in the universe. By building familiarity with previous Unit 1 ideas related to forces and energy, Unit 2 allows students to use and extend this knowledge to explain phenomena and solve design problems when investigating the distance and motion of various planetary objects to the force of gravity.

Big Ideas:

ESS1.A The Universe and Its Stars	1. Patterns of motion of the sun and moon (in our solar system, located within the Milky Way galaxy) and other stars (in other galaxies) can be observed and predicted. (MS-ESS1-1; MS-ESS1-2)
ESS1.B Earth and the Solar System	2. The regular orbital motions of the planets around the sun and moons around the planets are explained by gravitational forces. (MS-ESS1-2; MS-ESS1-3) 3. The position and motions of Earth relative to other objects in the solar system explain phenomena of eclipses and seasons. (MS-ESS1-1)
PS2.B Types of Interactions	4. Gravitational force attracts objects to one another; its strength depends on the objects’ mass and distance between objects. (MS-PS2-4)

The SIPS Unit 2 Student Profile describes what students should know and be able to demonstrate prior to and at the culmination of three-dimensional science instruction in Unit 2 to prepare for new and increasingly sophisticated learning opportunities in Unit 3.

Next Generation Science Standards (NGSS) Performance Expectations & Foundation Boxes

MS-ESS1-1 Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons. [Clarification Statement: Examples of models can be physical, graphical, or conceptual.]

MS-ESS1-3 Analyze and interpret data to determine scale properties of objects in the solar system. [Clarification Statement: Emphasis is on the analysis of data from Earth-based instruments, space-based telescopes, and spacecraft to determine similarities and differences among solar system objects. Examples of scale properties include the sizes of an object’s layers (such as crust and atmosphere), surface features (such as volcanoes), and orbital radius. Examples of data include statistical information, drawings and photographs, and models.] [*Assessment Boundary: Assessment does not include recalling facts about properties of the planets and other solar system bodies*.]

MS-PS2-4 Construct and present arguments using evidence to support the claim that gravitational interactions are attractive and depend on the masses of interacting objects. [Clarification Statement: Examples of evidence for arguments could include data generated from simulations or digital tools;

and charts displaying mass, strength of interaction, distance from the Sun, and orbital periods of objects within the solar system.] [*Assessment Boundary: Assessment does not include Newton's Law of Gravitation or Kepler's Laws.*]
MS-ESS1-2 Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system. [Clarification Statement: Emphasis for the model is on gravity as the force that holds together the solar system and Milky Way galaxy and controls orbital motions within them. Examples of models can be physical (such as the analogy of distance along a football field or computer visualizations of elliptical orbits) or conceptual (such as mathematical proportions relative to the size of familiar objects such as students' school or state).] [*Assessment Boundary: Assessment does not include Kepler's Laws of orbital motion or the apparent retrograde motion of the planets as viewed from Earth.*]

Targeted Scientific Practice(s)	Targeted DCI(s)	Targeted Cross-Cutting Concept(s)
[SEP-2] Developing and Using Models • Develop and use a model to describe phenomena. **(MS-ESS1-1) (MS-ESS1-2)** **[SEP-4]** Analyzing and Interpreting Data • Analyze and interpret data to determine similarities and differences in findings. (**MS-ESS1-3)** **[SEP-7]** Engaging in Argument from Evidence • Construct and present oral and written arguments supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem. **(MS-PS2-4)**	**ESS1.A:** The Universe and Its Stars • Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. **(MS-ESS1-1)** • Earth and its solar system are part of the Milky Way galaxy which is one of many galaxies in the universe. **(MS-ESS1-2)** **ESS1.B:** Earth and the Solar System • This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. **(MS-ESS1-3)** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. **(MS-ESS1-2) (MS-ESS1-3)** • The solar system appears to have formed from a disk of	**[CCC-1]** Patterns • Patterns can be used to identify cause-and-effect relationships. **(MS-ESS1-1)** **[CCC-3]** Scale, Proportion, and Quantity • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. **(MS-ESS1-3)** **[CCC-4]** System and System Models • Models can be used to represent systems and their interactions—such as inputs, processes, and outputs—and energy and matter flows within systems. **(MS-PS2-4) (MS-ESS1-2)** ***Connections to Nature of Science*** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation. **Interdependence of Science, Engineering, and Technology** • Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have

	dust and gas, drawn together by gravity. **(MS-ESS1-2)** **PS2.B:** Types of Interactions • Gravitational forces are always attractive. There is a gravitational force between any two masses, *but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun.* **(MS-PS2-4)**	led to the development of entire industries and engineered systems. **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** • Science assumes that objects and events in natural systems occur in consistent patterns that are understandable through measurement and observation.

Acquisition Goals

Acquisition Goals are multi-dimensional knowledge-in-use statements that integrate aspects of the NGSS dimensions (SEP & DCI or SEP & DCI & CCC) but are smaller in breadth than a performance expectation. Acquisition Goals describe the essential concepts and key skills a student must acquire to obtain mastery of the unit's objectives and emphasize student understanding as rooted in engagement with the science and engineering practices and not in memorization of science facts. The acquisition goals intentionally include SEP and CCC from outside of the unit's PE bundle.

Students will know and be able to . . .

A1. Obtain, evaluate, and/or communicate information that gravitational forces are always attractive.
A2. Obtain, evaluate, and/or communicate information that human-scale objects do not exert a strong (i.e., readily observable) gravitational force on one another.
A3. Develop a model that illustrates that the mass of two objects affects the gravitational forces between those objects.
A4. Construct and present an argument to support an explanation that gravitational forces are always attractive (or refute an explanation that gravitational forces can be repulsive).
A5. Analyze and interpret data on gravitational forces exerted by massive objects to show similarities and/or differences in the observed effects of those forces.
A6. Obtain and analyze data on the length of the day and relate it to the amount of energy received from the sun in a given location.
A7. Construct a model of Earth within the Earth-sun system that includes the tilt of Earth and that accounts for the seasonal variation in the amount of sunlight.
A8. Construct an explanation of the relationship between the amount of solar energy in terms of Earth's position within its orbit around the sun.
A9. Use a model of the Earth/sun system to show how different hemispheres will experience different amounts of sunlight during the orbit of Earth around the sun.
A10. Develop and use a model of the Earth-sun-moon system to describe the cyclic patterns of lunar phases, eclipses of the sun and moon, and seasons.
A11. Use the evidence of the path of a solar eclipse across the Earth's surface to explain the relative position of the moon between the Earth and the sun.
A12. Develop a model to describe that our solar system is located within the Milky Way galaxy, one of many galaxies in the universe.
A13. Obtain, evaluate, and/or communicate information that our solar system is located within the Milky Way galaxy, one of many galaxies in the universe.

A14. Obtain, evaluate, and/or communicate information that our solar system includes multiple types of objects that orbit the Sun (and may also orbit one another). **A15.** Construct and present an argument to support or refute an explanation that our solar system includes multiple types of objects that orbit the sun (and may also orbit one another). **A16.** Use data on orbital motions, including distances, to determine the relative masses of different objects in an orbital system. **A17.** Construct a model of a two-body system showing the attractive forces and their impact on the motion of the two objects relative to one another. **A18.** Construct a model showing that the equal and opposite force of gravity will lead to a much greater change in motion of a lighter object compared to a heavier object. **A19.** Construct and present an argument about how gravitational forces lead to a regular orbital motion of a moving object.
Cross-curricular Integration
Students develop an understanding of Earth and its solar system, including the patterns of apparent motion and interactions of objects such as the Earth, sun, moon, planets, and stars in the sky and that gravitational force between objects is attractive and its strength depends on the objects' mass and distance. Students develop these understandings by analyzing and interpreting data, developing and using models, and using evidence and observable patterns to construct and support arguments. Students use **reading** and **research** skills to acquire **new information** and **draw on** and **integrate information** from **multiple sources**, and **construct arguments** with strong **reasoning** and **evidence**. Students also use **mathematical practices** such as reasoning and modeling and **mathematical concepts** related to **ratios and proportional relationships** to explain phenomena or create solutions to design problems.

Common Core State Standards for Literacy	Common Core State Standards for Mathematics
Speaking and Listening **SL.8.5** Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. **(MS-ESS1-1), (MS-ESS1-2)** ***Reading Science and Technical Subjects*** **RST.6-8.1** Cite specific textual evidence to support analysis of science and technical texts. **(MS-ESS1-3)** **RST.6-8.7** Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). **(MS-ESS1-3)** ***Writing Science and Technical Subjects*** **WHST.6-8.1** Write arguments focused on *discipline-specific content*. (MS-PS2-4)	***Mathematical Practice*** **MP.2.** Reason abstractly and quantitatively. **(MS-ESS1-3)** **MP.4** Model with mathematics. **(MS-ESS1-1), (MS-ESS1-2)** ***Ratios and Proportional Relationships*** **6.RP.A.1** Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. **(MS-ESS1-1), (MS-ESS1-3), (MS-ESS1-2)** **7.RP.A.2** Recognize and represent proportional relationships between quantities. **(MS-ESS1-1), (MS-ESS1-3), (MS-ESS1-2)**

Science
Grade: 8 Unit: 2
42 days of instruction

Enduring Understandings	*Essential Questions*
Students will understand that . . . **EU1.** Earth and its solar system are in the Milky Way galaxy—one of many galaxies in a vast universe that has developed over billions of years beginning with a period of extreme and rapid expansion. **EU2.** The motion of the Earth and moon relative to the sun causes predictable patterns of daily, monthly, and yearly cycles on the Earth. **EU3.** Gravity is a force that governs the motions of objects on Earth, in the solar system, and in the universe. **EU4.** Models are used in a variety of scientific disciplines to help scientists and engineers visualize or explain a phenomenon, analyze past data, or make predictions about the future. **EU5.** Scientists obtain, analyze, and interpret data related to the orbital motion of objects, including large-scale structures such as the solar system, to support claims related to how gravitational forces between any two masses are always attractive.	**EQ1.** What is the universe, and what is Earth's place in it? **EQ2.** How do Earth's position and motion relative to other objects in the solar system explain observable phenomena? **EQ3**. How does the force of gravity affect the movement of objects, both on Earth and in the solar system? **EQ4**. How are scientific models used to predict and understand real-world situations or scientific phenomena? **EQ5**. How do I construct an argument using evidence to evaluate a scientific claim?

Vocabulary		
• Mass • Binary star • Gravitational force • Solar system • Galaxy • Rotation vs. revolution • Tilt (in relation to an axis) • Satellite • Elliptical orbit • Nebula • Interstellar medium • Protostar • Main sequence star • Solar energy	• Negligible forces/non-negligible forces • Relative motion • Universe • Proportional relationships • Inertia • Terrestrial planet • Gas giant • Planetary rings • Celestial object • Star nurseries • Force fields • Asteroids • Solar radiation	• Dwarf planet • Inner planet • Outer planet • Comet • Cyclic motion • Earth-sun-moon system • Lunar phase • Axis • Astronomical unit • Scale (and 'scale model') • Half moon • New moon • Geocentric / Heliocentric • Solar insolation

Science
Grade: 8 Unit: 2
42 days of instruction

Stage 2 – Assessment Evidence
Assessment Overview
For each of the acquisition goals listed in the Stage 1 - Desired Results, evidence statements were developed. These statements provide information on what we would want to see students do in order to determine the degree to which students have met the acquisition goals. These acquisition goals and evidence statements were then sequenced into instructional segments. Acquisition goals and evidence statements that were deemed critical were identified and assessment opportunities were developed. For this unit, three segments were identified. An overview of each segment is provided below. **Instructional Segment 1** focuses on Big Ideas 2 and 4 and students' ability to describe gravitational forces. Students are formally assessed on their ability to obtain, communicate, and evaluate information, develop models, and construct arguments related to different aspects of how gravitational forces interact with objects in the solar system. Students are informally assessed on their ability to obtain information on gravitational forces and their ability to analyze, interpret, and use data about gravitational forces and the mass of objects. **Instructional Segment 2** focuses on Big Idea 3 and students' ability to identify and use patterns of objects in our solar system to explain phenomena. Students are informally and formally assessed on their ability to obtain data and construct models to describe and construct explanations about patterns of the Earth-sun-moon system. **Instructional Segment 3** focuses on Big Idea 1 and students' ability to develop models to relate gravitational forces to observable patterns of orbital motion in solar systems. Students are formally assessed on their ability to obtain, evaluate, and communicate information and develop models about these systems. Communication includes developing models and presenting arguments related to the presence and locations of objects and systems within the universe and/or within the Milky Way galaxy. Students are informally assessed on their ability to obtain, evaluate, and communicate information about our solar system. **End-of-Unit Stackable, Instructionally-embedded, Portable Science (SIPS) Assessment:** For the end-of-unit SIPS assessment, students engage in three scenario-based assessment tasks. The tasks focus on the PEs: MS-ESS1-1, MS-ESS1-3, MS-PS2-4, MS-ESS1-2.
Instructionally-Embedded Assessments
For each instructional segment, descriptions of *informal* and *formal* instructionally-embedded assessments are included based on the acquisition goals and evidence statements deemed critical to assess along an instructional plan. Informal assessments defined as "in the moment" assessment opportunities identify student challenges and lack of knowledge or misconceptions and could include class check-ins such as discussion prompts, exit tickets, or graphic organizers. Formal assessments measure how well students perform when engaging with more complex tasks that require integration of the dimensions (SEPs, DCIs, CCCs) in the service of sense-making. They are administered at specific, intentional points in time along an instructional plan before or after a lesson or a series of lessons. Examples include performance tasks, concept maps, research projects, or hands-on tasks.

Instructionally-embedded Assessments for Use during Instructional Segment 1

Informal Assessment: Nature of Gravitational Forces

At various points in time during Segment 1, educators may use informal classroom check-ins (e.g., exit tickets, in-the-moment questions) to gather evidence about students' ability to obtain, evaluate, and communicate evidence to support explanations and to create models that show that gravitational forces between two objects are always attractive. Through simulations, students analyze and interpret data on gravitational data exerted by massive objects and develop models that show how the gravitational force between two objects with varying masses is affected. Students are evaluated on their ability to relate their findings back to the James Webb Space Telescope (the anchoring phenomenon) and Earth, moon, and sun, and to ask questions related to the masses of objects and exertion of negligible/nonnegligible gravitational forces.

Assessment Purpose and Use

- The purpose of this assessment is to determine whether students can obtain information from reliable sources, evaluate forces based on the nature of gravitational forces, and support a claim that human-scale objects do not exert strong (observable) gravitational forces. The teacher may use this assessment to determine whether more instruction is needed in obtaining information.

Administration Time: 5-10 minutes

Scoring Time: 10 minutes

Assessment Type

Informal - Exit Ticket

Informal - Classroom Check-In

Assessment Sub-Type(s)

Exit Tickets

Scenario/Phenomena-based Assessment Task

Discussion prompts

In-the-moment Questions

This assessment will assess students' ability to:

- Identify information that supports the idea that gravitational forces are always attractive.
- Communicate information from science and technical texts to support the claim that gravitational interactions are attractive.
- Describe scientific evidence about how gravitational interactions are always attractive between interacting objects.
- Identify information that supports a claim that human-scale objects do not exert a strong (i.e., readily observable) gravitational force on one another.
- Describe scientific evidence about how gravitational interactions on human-scale objects do not exert a strong (i.e., readily observable) gravitational force on one another.
- Describe how a model supports the idea that the mass of two objects affects the gravitational forces between those objects.
- Develop and use models to show how the mass of two objects affects the gravitational forces between those objects.
- Describe the relevant relationships between components shown in a model of a phenomenon (i.e., the mass of two objects affects the gravitational forces between those objects) related to the relative magnitude and direction of the force each object exerts on the other.

Science
Grade: 8 Unit: 2
42 days of instruction

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):

- The James Webb Space Telescope
- Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects
- Do I Have Gravity?

NGSS PEs:	CCSS:	EUs/EQs:	AGs:
MS-PS2-4	WHST.6-8.1	EU3/EQ3	A1
		EU5/EQ5	A2
			A3
			A5

Informal Assessment: Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects

During the lesson, *Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects*, students are asked to study data/evidence related to the relative masses of objects and the magnitudes of forces to explain similarities and differences between various interactions that occur in a uniform circular motion. In this assessment, from this study and analysis of data and evidence, students evaluate and draw conclusions from their data that there is the presence of gravitational force between massive objects and all other objects if they have mass.

Assessment Purpose and Use

- Gauge where students are in their learning, identify what challenges students are facing, and determine next steps for the class and/or individual students.
- Provide information that can be used either at the class level or the individual student level to help determine what instructional activities best support students.

Administration Time: 5-10 minutes

Scoring Time: 5-10 minutes

Assessment Type

Informal - Exit Ticket

Informal - Classroom Check-In

Assessment Sub-Type(s)

In-the-moment Questions

Exit Tickets

Discussion prompts

This assessment will assess students' ability to:

- Use data to support an explanation of the similarities and differences in forces exhibited with objects of varying masses based on mass and gravitational force.
- Identify evidence, data, or a model that supports an argument that gravitational interactions between two massive objects are nonnegligible.
- Use data on gravitational forces exerted by massive objects to show similarities and/or differences in the observed effects of those forces.
- Use data to answer questions related to orbital motions, including distances, to determine the relative masses of different objects in an orbital system.
- Use data to support an explanation of the relative masses of different objects in an orbital system based on orbital motions, including distances.

Science
Grade: 8 Unit: 2
42 days of instruction

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects	MS-PS2-4	WHST.6-8.1	EU3/EQ3	A3*
				A5
				A16

Informal Assessment: **Using Gravity to Find Alien Worlds**

Students make sense of the relationships between masses of planetary objects and orbital motion to discover that objects with smaller masses tend to orbit objects with larger masses and that those motions impact the larger object's motion. In this assessment, students are provided with orbital data on an unknown system of objects and make predictions of the relative masses of those objects to determine which objects have other objects orbiting them.

Assessment Purpose and Use

- This assessment should be used to determine whether students can use patterns in data to make predictions about orbital relationships between objects of differing masses.
- The teacher may use this assessment to determine whether more instruction is needed for using patterns in data.

Administration Time: 5 minutes

Scoring Time: 10 minutes

Assessment Type

Informal - Exit Ticket

Informal - Classroom Check-In

Assessment Sub-Type(s)

Exit Tickets

In-the-moment Questions

Discussion prompts

In-the-moment Questions

This assessment will assess students' ability to:

- Use data to support an explanation of the relative masses of different objects in an orbital system based on orbital motions, including distances.
- Use data to answer questions related to orbital motions, including distances, to determine the relative masses of different objects in an orbital system.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
Using Gravity to Find Alien Worlds	MS-ESS1-2	7.RP.A.2	EU3/EQ3	A16

Formal Assessment: Develop a Model of Gravitational Force Showing the Relationship with Mass

Students use the information gathered in the lessons *The James Webb Space Telescope* and *Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects* to construct and describe a model of a system of objects that demonstrates the relationship between gravitational forces and the masses of the objects. In this assessment, students are given a specific, familiar system (e.g., Earth-sun-moon system) with information about mass provided and construct a model showing the forces between the objects. After constructing the model, students write an explanation of how the model supports the claim that gravitational forces depend on mass and describe how they decided which direction and what sizes to draw the arrows.

Assessment Purpose and Use

- This assessment should be used to inform the teacher about student understanding of the relationships between mass and gravitational forces. This is an opportunity to dig deeper than the first unit into this relationship, so it should focus on how the force changes when the masses of the objects change and correct any student misconceptions from the first unit.
- This is an opportunity to formally assess students' ability to model phenomena since they have also learned this skill previously.
- The teacher may use this assessment to determine whether more instruction is needed in supporting a claim with evidence (the model) and reasoning (the explanation of the model).

Administration Time: 40 minutes

Scoring Time: 10 minutes

Assessment Type

Formal – Performance Task

Assessment Sub-Type(s)

Scenario/Phenomena-based Assessment Task

This assessment will assess students' ability to:

- Describe how a model supports the idea that the mass of two objects affects the gravitational forces between those objects.
- Use models to show how the mass of two objects affects the gravitational forces between those objects.
- Describe the relevant relationships between components shown in a model of a phenomenon (i.e., the mass of two objects affects the gravitational forces between those objects) related to the relative magnitude and direction of the force each object exerts on the other.
- Develop a model that supports the idea that the mass of two objects affects the gravitational forces between those objects.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects • How Does JWST Stay in Orbit?	MS-PS2-4	7.RP.A.2	EU3/EQ3 EU4/EQ4	A3

Formal Assessment: Modeling How Gravitational Forces Affect Motion

This assessment is a performance evaluation of how well students understand and can model the relationships between force, mass, and relative motion in two body systems. In this assessment, students work in groups of three to four and use everyday objects to develop a model or two models of a two-body system to demonstrate their understanding of the relationships between gravitational forces, mass, and relative motion of objects.

Science
Grade: 8 Unit: 2
42 days of instruction

Assessment Purpose and Use

- This assessment should be used to determine whether students can use data, develop a model, describe relationships between components in a model, and explain that Newton's third law forces affect motion differently for objects of different masses.

Administration Time: 40 minutes

Scoring Time: 10 minutes

Assessment Type

Formal – Performance Task

Assessment Sub-Type(s)

Hands-on Task

This assessment will assess students' ability to:

- Use models to show the relationship between the attractive force of gravity acting upon two objects and their masses (linear) and/or the distance separating them.
- Describe the relevant relationships between components needed and include appropriate vector quantities to develop a model to explain the phenomenon (i.e., gravity is a predominantly inward-pulling force that can keep smaller/less massive objects in orbit around larger/more massive objects).
- Develop a model that shows the attractive forces in a two-body system and the impact of the forces on the motion of the two objects relative to one another.
- Develop and use a model to support the idea that the equal and opposite force of gravity will lead to a much greater change in motion of a lighter object compared to a heavier object.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Modeling How Gravitational Forces Affect Motion	MS-ESS1-2	7.RP.A.2	EU3/EQ3	A17
			EU4/EQ4	A18

Formal Assessment: Forces Modeling How Gravitational Forces Affect Motion

This is the culminating assessment for Segment 1 in which students use their understanding of gravitational interactions to explain concepts related to the anchor phenomenon: James Webb Space Telescope.

Assessment Purpose and Use

- This assessment should be used to determine if students have challenges using data to support/refute an explanation about gravitational forces, determining whether forces between objects are negligible/nonnegligible given data about the masses of the object, or discussing how an object's mass determines its relative motion.

Administration Time: 30 minutes

Scoring Time: 10 minutes

Assessment Type

Formal – Quiz

Assessment Sub-Type(s)

Scenario/Phenomena-based Assessment Task

Sample Formative Assessment Task:
"Forces Modeling How Gravitational Forces Affect Motion"

This assessment will assess students' ability to:

- Communicate information from science and technical texts to support the claim that gravitational interactions are attractive.
- Use data on mass and gravitational force to determine similarities and differences in forces exhibited with objects of varying masses.
- Identify evidence or data that supports an explanation that gravitational forces are always attractive.
- Use reasoning to connect appropriate evidence about the forces on objects and construct the argument that gravitational forces are attractive.
- Identify evidence, data, or models that support an argument that gravity causes a pattern of smaller/less massive objects orbiting around larger/more massive objects at all system scales in the universe.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• How Does JWST Stay in Orbit? • Modeling How Gravitational Forces Affect Motion	MS-ESS1-2 MS-PS2-4	WHST.6-8.1	EU3/EQ3 EU5/EQ5	A4 A19

Instructionally-embedded Assessments for Use during Instructional Segment 2

Informal Assessment: Develop and Use Models of the Earth-Sun-Moon System

At various points in time during Segment 2, educators may use informal classroom check-ins (e.g., exit tickets, in-the-moment questions) to use data and models as evidence to describe and identify relationships between the position of the Earth and the amount of sunlight received and explain the existing relationships in the Earth-moon-sun system from cyclic patterns of lunar phases, eclipses of the sun, and seasons.

Assessment Purpose and Use

- These informal assessments are typically used for formative purposes. The goal is to gauge where students are in their learning, identify what challenges students are facing, and determine the next steps for the class and/or individual students.
- The assessments provide information that can be used either at the class level or the individual student level to help determine what instructional activities best support students.

Administration Time: 10 minutes

Scoring Time: 1 minute per question

Assessment Type

Informal - Classroom Check-In

Assessment Sub-Type(s)

Exit Tickets

In-the-moment Questions

Discussion prompts

This assessment will assess students' ability to:

- Describe how the length of the day is related to the amount of energy received from the sun in a given location.
- Describe scientific evidence about the relationship between the length of the day and its relationship to the amount of energy received from the sun in a given location.

- Identify the evidence that supports a claim related to the relationship of the amount of solar energy reaching Earth in terms of Earth's position within its orbit around the sun.
- Construct an explanation to support a claim related to the relationship of the amount of solar energy reaching Earth in terms of Earth's position within its orbit around the sun.
- Describe how a model supports the idea that different hemispheres will experience different amounts of sunlight during the orbit of Earth around the sun.
- Describe the relevant relationships between Earth and the sun and how it shows how different hemispheres will experience different amounts of sunlight during Earth's orbit around the sun.
- Describe the relevant relationships among components of a given model to explain the phenomenon (i.e., different hemispheres will experience different amounts of sunlight during the orbit of Earth around the sun).
- Develop and use a model to describe the cyclic patterns of lunar phases and eclipses of the sun and moon, and to describe the seasons.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):

- Modeling How Gravitational Forces Affect Motion (Segment 1)
- Where Are We?
- Observing the Sun, Earth, and Moon
- Solar Energy and Seasons
- Comparing Our Model to Other Models

NGSS PEs:	CCSS:	EUs/EQs:	AGs:
MS-ESS1-1	MP.2	EU2/EQ2	A6
	7.RP.A.2	EU4/EQ4	A8
	RST.6-8.7		A9
			A10

Formal Assessment: Develop and Use Models of Earth's Tilt and Seasons

This assessment begins after students discuss the reasons for the JWST to have a sun shield during the lesson, *Where Are We?* Students develop a model of the Earth and sun that demonstrates how the tilt of the Earth causes different parts of the planet to receive varied amounts of energy over the course of the year. Students should be prepared to demonstrate how their model simulates the locations and positions in orbit that produce various seasons in the Northern or Southern hemispheres, differences in daylight hours for different hemispheres, and how solar energy received by various locations changes during the revolution around the sun.

Note: Models should be made accessible to students throughout the course of instruction that can be refined, referenced, and utilized in multiple lessons.

Assessment Purpose and Use

- The purpose of this task is to measure how well students are able to engage in three-dimensional thinking when developing a model.
- The teacher can use this to engage students with more complex tasks and determine if students need support with these concepts.

Administration Time: 30 minutes

Scoring Time: 5 minutes per partner group

Assessment Type

Formal - Extended Performance Task

Assessment Sub-Type(s)

Extended Project

This assessment will assess students' ability to:

- Develop a model of the Earth within the Earth-sun system that includes the tilt of the Earth and accounts for the seasonal variation in the amount of sunlight.
- Use models to show how the change in season at a given place on Earth is directly related to the orientation of the tilted Earth and the position of Earth in its orbit around the sun.
- Describe how a model supports the idea that the tilt of the Earth accounts for the seasonal variation in the amount of sunlight.
- Describe how a model supports the idea that different hemispheres will experience different amounts of sunlight during the orbit of Earth around the sun.
- Describe the relevant relationships between Earth and the sun and how different hemispheres will experience different amounts of sunlight during Earth's orbit around the sun.
- Describe the relevant relationships among components of a given model that are relevant to explain the phenomenon (i.e., the tilt of the Earth accounts for the seasonal variation in the amount of sunlight; different hemispheres will experience different amounts of sunlight during the orbit of Earth around the sun.).

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Where Are We?	MS-ESS1-1	MP.2	EU2/EQ2	A7
• Solar Energy and Seasons		7.RP.A.2	EU4/EQ4	A9
		RST.6-8.7		A10*

Formal Assessment: Observing the Sun, Earth, and Moon

After exploring content related to lunar phases and solar eclipses and using models of the Earth-sun-moon system, students use provided materials to construct a model of the Earth-sun-moon system to represent these phenomena.

Assessment Purpose and Use

- The purpose of this task is to measure how well students are able to engage in three-dimensional thinking when developing a model.
- The teacher can use this to engage students with more complex tasks and determine if students need support with these concepts.

Administration Time: 40 minutes

Scoring Time: 5-10 minutes per group

Assessment Type

Formal - Short Performance Task

Assessment Sub-Type(s)

Scenario/Phenomena-based Assessment Task

Hands-on Task

This assessment will assess students' ability to:

- Develop and use a model to describe the cyclic patterns of lunar phases and eclipses of the sun and moon, and to describe the seasons.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Observing the Sun, Earth, and Moon	MS-ESS1-1	RST.6-8.7	EU2/EQ2	A10
		6.RP.A.1	EU4/EQ4	
		WHST.6-8.1		

Formal Assessment: Comparing Our Model to Other Models

This is the culminating assessment for Segment 2 in which students review and evaluate other models that provide explanations about the Earth-sun-moon system. Students revise their explanations about how changing amounts of solar energy result in the seasonal cycling of temperature. In groups, students write a summary of their comparisons of other models to the ones developed during the segment and prepare a class presentation.

Assessment Purpose and Use

- The purpose of this task is to measure how well students are able to engage in three-dimensional thinking when developing a model.
- The teacher can use this to engage students with more complex tasks and determine if students need support with these concepts.

Administration Time: 120 minutes

Scoring Time: 20 minutes

Assessment Type

Formal - Research Project

Assessment Sub-Type(s)

Research Report

Sample Formative Assessment Task:
“Comparing Our Model to Other Models”

This assessment will assess students’ ability to:

- Use models to show how the change in season at a given place on Earth is directly related to the orientation of the tilted Earth and the position of Earth in its orbit around the sun.
- Describe the relevant relationships between components shown in an Earth-sun model showing how the tilt of Earth accounts for the seasonal variation in the amount of sunlight.
- Develop a model of Earth within the Earth-sun system that includes the tilt of Earth and accounts for the seasonal variation in the amount of sunlight.
- Identify the evidence that supports a claim related to the relationship of the amount of solar energy reaching Earth in terms of Earth's position within its orbit around the sun.
- Construct an explanation to support a claim related to the relationship of the amount of solar energy reaching Earth in terms of Earth's position within its orbit around the sun.
- Develop and use a model to describe the cyclic patterns of lunar phases and eclipses of the sun and moon, and to describe the seasons.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Comparing Our Model to Other Models	MS-ESS1-1	RST.6-8.7	EU2/EQ2	A7
		6.RP.A.1	EU4/EQ4	A8
		WHST.6-8.1		A10

Instructionally-embedded Assessments for Use during Instructional Segment 3

Informal Assessment: Lumpy Space? Empty Space? Why is Our Universe the Way it is?

In this assessment, after gathering and evaluating evidence related to the objects in our solar system, students demonstrate their ability to effectively identify and share information related to our solar system, the Milky Way Galaxy, and the universe.

Assessment Purpose and Use

- Informal assessments are typically used for formative purposes.
- The goal is to gauge where students are in their learning, identify what challenges students are facing, and determine next steps for the class and/or individual students.
- The assessments provide information that can be used either at the class level or the individual student level to help determine what instructional activities will best support students.
- These informal assessments should be given throughout the instruction to help inform future instruction and the need for remediation.

Administration Time: 5 minutes

Scoring Time: 2-3 minutes

Assessment Type

Informal - Classroom Check-In

Assessment Sub-Type(s)

Discussion prompts

Graphic Organizers

Exit Tickets

In-the-moment Questions

This assessment will assess students' ability to:

- Identify information that supports the idea that our solar system is located within the Milky Way galaxy, one of the many galaxies in the universe.
- Describe (in degrees of magnitude) the relative spatial scales involved from solar systems to galaxies to broader clusters in the universe.
- Describe scientific evidence about how scale (in mass, distance, and time) is a factor determining which components are relevant when understanding the solar system, galaxy, or universe.
- Identify information that supports the idea that our solar system includes multiple types of objects that orbit the Sun.
- Describe the relationships among objects in our solar system as a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- Describe scientific evidence of Earth's relative position within our solar system.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Lumpy Space? Empty Space? Why is Our Universe the Way it is?	MS-ESS1-1	SL.8.5	EU1/EQ1	A13
		RST.6-8.1	EU4/EQ4	A14
		RST.6-8.7		
		WHST.6-8.1		

Science
Grade: 8 Unit: 2
42 days of instruction

Formal Assessment: Modeling Earth, Our Solar System, and Our Galaxy: "Around We Go"

In this assessment, after gathering and evaluating the evidence related to the objects in our solar system and creating models of our solar system, students use and develop models to show the relationship between objects in our solar system, the Milky Way Galaxy, and the universe.

Assessment Purpose and Use

- Performance tasks provide opportunities for students to engage with the practices of the discipline along with the content.
- These tasks are used to measure how well students perform when provided more complex tasks and are opportunities to engage in a meaningful way with the content in the curriculum.

Administration Time: 30 minutes

Scoring Time: 5 minutes

Assessment Type

Formal - Short Performance Task

Assessment Sub-Type(s)

Scenario/Phenomena-based Assessment Task

Design Project

This assessment will assess students' ability to:

- Describe how a model supports the idea that Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
- Use models to show the relationship between Earth and its solar system as part of the Milky Way galaxy, which is one of many galaxies in the universe.
- Describe the relevant relationships between components needed to develop a model showing celestial objects, including Earth.
- Develop a model that supports the idea that Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Modeling Earth, Our Solar System, and Our Galaxy: "Around We Go"	MS-ESS1-1	RST.6-8.7	EU1/EQ1	A12
		MP.4	EU4/EQ4	

Formal Assessment: Using Evidence to Develop an Argument about Objects in Our Solar System

In this assessment, after gathering information about our solar system, galaxy, and universe, practicing obtaining and evaluating relevant data, and developing and using models, students identify evidence and provide their reasoning to support a claim that our solar system includes multiple types of objects that orbit the sun and that some of these objects also orbit one another.

Note: Models should be made accessible to students throughout the course of instruction that can be refined, referenced, and utilized in multiple lessons.

Science
Grade: 8 Unit: 2
42 days of instruction

Assessment Purpose and Use

- Performance tasks provide opportunities for students to engage with the practices of the discipline along with the content.
- These tasks are used to measure how well students perform when provided more complex tasks and are opportunities to engage in a meaningful way with the content in the curriculum.

Administration Time: 30 minutes
Scoring Time: 5 minutes
Assessment Type
Formal - Short Performance Task
Assessment Sub-Type(s)
Scenario/Phenomena-based Assessment Task

This assessment will assess students' ability to:

- Identify information that supports the idea that our solar system is located within the Milky Way galaxy, one of the many galaxies in the universe.
- Describe (in degrees of magnitude) the relative spatial scales involved from solar systems to galaxies to broader clusters in the universe.
- Describe scientific evidence about how scale (in mass, distance, and time) is a factor determining which components are relevant when understanding the solar system, galaxy, or universe.
- Identify information that supports the idea that our solar system includes multiple types of objects that orbit the sun.
- Describe the relationships among objects in our solar system as a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):	NGSS PEs:	CCSS:	EUs/EQs:	AGs:
• Gravity Pulls Us All Together	MS-ESS1-1	SL.8.5	EU1/EQ1	A13
• Rotating Discs in Space		RST.6-8.1	EU5/EQ5	A14
• Modeling Earth, Our Solar System, and Our Galaxy: "Around We Go"		RST.6-8.7		

Formal Assessment: Communicating About Objects in Our Solar System, The Milky Way, and the Universe

Having researched the formation, shape, and make up of some of the objects in space, students communicate that learning to an audience that makes sense for the community. For example, students may be tasked with creating a presentation for their learning at a science fair, for younger audiences, creating a video for YouTube, or at a talk at a local museum, educational books/graphic novels, a series of educational posters, or some other idea that is relevant to students. Students are provided with a variety of options for their presentations and the media. Students should clearly state whether they are accepting or rejecting a claim, the evidence in support of this position, and their reasoning for why/how the assembled evidence supports their position. Students' specific arguments will differ depending on the claim. But generally, their arguments should include that our solar system includes multiple types of objects that orbit the sun (and may also orbit one another).

Assessment Purpose and Use

- Performance tasks provide opportunities for students to engage with the practices of the discipline along with the content.
- These tasks are used to measure how well students perform when provided more complex tasks and are opportunities to engage in a meaningful way with the content in the curriculum.
- The teacher can use this assessment to determine what challenges students have with constructing arguments.

Administration Time: 60 minutes

Scoring Time: 5 minutes

Assessment Type

Formal - Extended Performance Task

Assessment Sub-Type(s)

Scenario/Phenomena-based Assessment Task

Research Report

Extended Project

This assessment will assess students' ability to:

- Identify information that supports the idea that our solar system includes multiple types of objects that orbit the sun.
- Describe the relationships among objects in our solar system as a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.
- Describe scientific evidence of Earth's relative position within our solar system.
- Identify evidence, data, or models that support an argument that our solar system includes multiple types of objects that orbit the sun.
- Use evidence, data, or a model to support an argument that our solar system includes multiple types of objects that orbit the sun (and may also orbit one another).

Stage 1 & Stage 3 Associations

Stage 3 Connection(s):

- Gravity Pulls Us All Together
- Rotating Discs in Space
- Modeling Earth, Our Solar System, and Our Galaxy: "Around We Go"

NGSS PEs:	CCSS:	EUs/EQs:	AGs:
MS-ESS1-1	SL.8.5	EU1/EQ1	A14
MS-ESS1-2	RST.6-8.1	EU5/EQ5	A15
	RST.6-8.7		
	WHST.6-8.1		

Guidance for Equitable Assessments for Diverse Learners

How do we optimize accessibility for diverse learners and why is this important? Designing Equitable Assessments for Diverse Learners provides steps to planning and developing equitable assessments that incorporate the principles of Universal Design for Learning (UDL) and the elements of Universally Designed Assessments (UDA). Both UDL and UDA are designed to provide access to instruction and/or assessment to the widest range of students. This includes, but is not limited to, students with varying abilities, cultures, primary languages, background knowledge, and interests. For more information about equitable assessment design and use, and why it is important, view *Chapter 4: Fairness and Accessibility* of the Strengthening Claims-based Interpretations and Uses of Local and Large-scale Science Assessment Scores (SCILLSS) Digital Workbook on Educational Assessment Design and Evaluation: Creating and Evaluating Effective Educational Assessments.

Stage 3 – Learning Plan

Learning Plan Rationale

The learning plan is based on an articulation of learning goals (i.e., NGSS PEs, CCSS, EUs/EQs, and acquisition goals (defined in Stage 1) distributed over four instructional segments. These learning goals are used in Stage 2 to identify and describe the assessments that will be used to assess (to collect evidence of) students' learning throughout the course of the unit and instruction. The lessons in Instructional Segments 1 through 3 are designed to ensure students have opportunities to acquire and apply the learning goals in Stage 1. The instructional segments in both Stage 2 and Stage 3 are similar in terms of the learning goals they represent. Assessments listed in Stage 2 for a segment might use (assess) fewer learning goals than are present in the respective Stage 3 but will not use additional learning goals (unless they were taught in a prior segment).

Unit Entrance

The unit opening focuses on students experiencing and discussing a phenomenon that sparks their interest and curiosity. To do so, the class engages with an "anchor phenomenon" and generates questions based on that phenomenon, posting their questions to the "driving question board." Some of the questions added to the driving question board can be used by the teacher to transition into Instructional Segment 1, by framing the lessons (and segment) as a means by which to investigate and answer some of the questions that students generate based on the anchor phenomenon.

Throughout the unit (e.g., after each instructional segment) the teacher returns to the driving question board and has students reflect on their recent learning, and which questions they can now answer based on their learning in the prior segment. Following this reflection, the teacher uses the driving question board again, this time identifying remaining unanswered (or partially answered) questions that can motivate the activities and investigations that are the focus of the next instructional segment.

Anchor Phenomenon

In this unit, the anchor phenomenon is based on the shared experience of having students watch a video that introduces The James Webb Space Telescope (JWST). The teacher can problematize this for students by setting up the following general questions: Why will the best images from JWST start to appear about six months after launch?[1] Does the JWST have the same orbit as the Hubble Space Telescope? What forces make it possible for the JWST to move as it did in the video? Why can't JWST move in a straight-line path after launch? How do objects in our solar system move and how do we know they move in these ways? How can we learn the evolution of our solar system from the JWST?

Details for this Anchor Phenomenon activity appear in the first lesson (The James Webb Space Telescope [Anchor Phenomenon]) in Instructional Segment 1. Note, the JWST is addressed in multiple lessons and is referenced in Segments 2 and 3.

Unit Framing

Framing for SIPS Instructional Framework

---

[1] Source: https://www.space.com/21925-james-webb-space-telescope-jwst.html

Science
Grade: 8 Unit: 2
42 days of instruction

The James Webb Space Telescope (JWST) is an infrared space observatory that launched from Earth on December 25, 2021. Webb is the successor of the Hubble Space Telescope. It will explore the cosmos to reveal the history of the universe from the Big Bang to alien planet information and more and is now in orbit in our solar system. Webb will allow scientists to study the formation of galaxies, planets outside of our solar system, and newborn stars. Webb is a massive telescope that looms three stories high and covers the size of a tennis court.

Resources:

- Orbit - Webb/NASA
  [https://jwst.nasa.gov/content/about/orbit.html]
- Lesson Plans, Activities, & Programs for Formal Education Webb Telescope/NASA
  [https://jwst.nasa.gov/content/forEducators/formal.html]
- Lesson Plans, Activities, & Programs for Informal Education Webb Telescope/NASA
  [https://jwst.nasa.gov/content/forEducators/informal.html]

Example Driving Questions

Potential/example driving questions that students might generate include:

- What keeps the telescope in orbit?
- Does the telescope need energy/fuel to stay in orbit?
- What will the telescope be able to see?
- Why is the JWST in orbit 1 million miles away?
- Does the JWST have the same orbit as Hubble?
- How far does Earth's gravity extend?
- Why do space rocket launches need to occur during a specific time of day?
- Why are telescopes important?
- Why do we need a space telescope (as opposed to a ground-based telescope)?

Problematization/Investigative Strategy for the Unit

If we want to understand our solar system, we'll need to research objects in our solar system and the Milky Way galaxy in the universe. We'll need to understand the apparent motion and patterns of objects in the sky that can be observed. What are the connections between gravitational forces, masses of objects, and orbital motion of objects? What causes eclipses, the seasons, and lunar phases?

Instructional Segment 1	
Learning Investigations and Sample Lessons	
Stage 1 Associations **NGSS PEs:** **MS-PS2-4** **MS-ESS1-2**	**Estimated Classroom Time: 800 minutes** **The James Webb Space Telescope (Anchor Phenomenon, Asking Questions)** • 5Es: Engage • Estimated Time: 50 minutes • AGs: A1*

Science
Grade: 8 Unit: 2
42 days of instruction

MS-ESS1-3 **CCSS:** **SL.8.5** **WHST.6-8.1** **7.RP.A.2** **EUs/EQs:** **EU3/EQ3** **EU4/EQ4** **EU5/EQ5** **AGs:** **A1** **A2** **A3** **A4** **A5** **A16** **A17** **A18** **A19***	For this unit of instruction, the James Webb Space Telescope (JWST) can be used as an anchoring phenomenon. If the teacher does not feel that this topic will resonate with their students, they should change the topic. The opening activity is focused on generating driving questions in which students work to "obtain, evaluate, and communicate" information throughout the unit. Students may or may not be familiar with the JWST. As an introduction to the telescope, students read What is the James Webb Space Telescope?, ask questions about the JWST, and begin to generate a driving question board. As students wrap up their first round of questions, the teacher shares with students a video that shows the path of the JWST. As they watch the video, they should document what they observe and questions they have and add those to the driving question board. As the class progresses through the unit, the teacher revisits the driving question board to check on questions to see if they have been answered, to add new questions, and to add important relevant observations/data. **Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects** • 5Es: Explore • Estimated Time: 250 minutes • AGs: A5, A16 Students revisit an activity from Unit 1 where they explored changing motion of an object in a uniform circular motion. This activity is commonly done in advanced classes and there are several examples for those spaces. However, for this activity at this grade level, students do not need to engage in complex calculations. Instead, the goal is for students to see that there is a relationship between how fast the object is moving, the radius of the circle, and the force. Students should see that the greater the mass hanging at the bottom (more force) that the rubber stopper will either rotate with a higher speed at the same radius or will rotate with a smaller radius to achieve the same speed. Students can also experiment with changing the stopper; if they do, they should find that the size of the stopper has no impact on the speed but will result in a greater force. (Force is proportional to the mass of the object and the speed and inversely related to the radius.) Reference: • Physics Lab [https://www.madison-schools.com/cms/lib/MS01001041/Centricity/Domain/3318/what%20keeps%20the%20stopper%20moving%20in%20a%20circle%20lab.pdf] After discussing this, the teacher asks students to consider how this might connect with the JWST. Ideally, students make connections between the activity and the motion of objects around the sun. The rubber stopper is the orbiting object, and

	the force on the spring scale is the net force on the JWST or any other orbiting object. Next, students study data/evidence related to the relative masses of objects, their radii of orbit, and other data that they deem relevant. This information could include a look at the sun/Earth/moon, binary stars, or other examples. Students should gather and analyze data to find patterns and see if their takeaways from the circular motion activity are reflected in the astronomical data. Students conclude from their data that there is the presence of a net force between massive objects and all other objects and that this force depends on the mass of the objects and their distance apart. (Note: the distance will be a larger factor; the teacher can support students in finding objects of similar distance but different masses. This may be easiest to accomplish by looking at objects in orbiting belts or comparing moons around individual gas giants. Students should find that speeds are close to the same for objects the same distance; if they recall from the previous unit, they may make the connection that a larger mass means that the force must be bigger if the change in motion is the same.) Resources: • Stars Inside of Other Stars - YouTube [https://www.youtube.com/watch?v=EU-HBPfbMKI] • Planetary Physical Parameters (nasa.gov) [https://ssd.jpl.nasa.gov/planets/phys_par.html] • Saturn - Moons | Britannica [https://www.britannica.com/place/Saturn-planet/Moons] **Sample Lesson:** "Analyze and Interpret Data" **Do I Have Gravity?** • 5Es: Explore • Estimated Time: 100 minutes • AGs: A1, A2, A3 In this lesson, students obtain, evaluate, and communicate information about how human-scale objects exert negligible gravitational forces. The teacher poses a question to students, "If everything that has mass has gravity, why don't we all have smaller objects orbiting us?" (For example: why aren't pencils/pens attracted to us and orbiting us?) Students consider, "why doesn't Jupiter pull us toward it?" Students record their initial thinking to revisit later. After students share their ideas in response to the question, students should explore the resources below to experiment with gravitational forces for the very massive and the very small. As they explore, students record data and observations that support or refute their initial thinking. Use this PhET simulation for human-sized objects: • Gravity Force Lab (colorado.edu)

[https://phet.colorado.edu/sims/html/gravity-force-lab/latest/gravity-force-lab_en.html]

Use this for reference to planetary-sized objects:

- Physics Simulation: Gravitational Fields (physicsclassroom.com) [https://www.physicsclassroom.com/Physics-Interactives/Circular-and-Satellite-Motion/Gravitational-Fields/Gravitational-Fields-Interactive]

Evaluate: The teacher asks students to talk in small groups about the forces they observed in their mini-labs. Then students revisit their question and the answer. Has their answer changed, why or why not?

As a class, students discuss the initial question. Using questions, the teacher encourages students to consider the scale between the two simulations and if they are familiar with negligible and nonnegligible. The teacher discusses with students what gravitational forces are acting on them and which ones are negligible and non-negligible.

How Does JWST Stay in Orbit?

- 5Es: Explain, Evaluate
- Estimated Time: 150 minutes
- AGs: A3, A4, A5

In this lesson, students revisit the animation from the opening lesson, *The James Webb Space Telescope*, which shows JWST in its orbit. Students explore additional resources to understand why JWST is located where it is and why it can stay in its orbit. Students read additional information about gravity and interplanetary forces.

Resources:

- Orbit - Webb/NASA
  [https://jwst.nasa.gov/content/about/orbit.html]
- Gravity and Orbits (colorado.edu)
  [http://phet.colorado.edu/sims/html/gravity-and-orbits/latest/gravity-and-orbits_en.html]
- The Mysterious Force of Gravity Explained by Neil deGrasse Tyson - YouTube
  [https://www.youtube.com/watch?v=ybxSgIBbBh8]

After conducting their additional research, students revisit the driving question board to select a question to answer and explain. Students may need additional support in selecting an appropriate question to use as part of a scientific explanation. After selecting a question, students either individually or in small groups review the information from the opening activity, the data analysis, and the additional research and use that information to support the development of a CER which answers their question. The construction of a scientific argument should be

	done through the Claim-Evidence-Reasoning (CER) model. This is an opportunity to remediate, if needed, this skill taught in the previous unit. **Modeling How Gravitational Forces Affect Motion** • 5Es: Explain, Evaluate • Estimated Time: 150 minutes • AGs: A17, A18, A19* In this lesson, students demonstrate how well they understand and can model the relationships between force, mass, and relative motion in two body systems. Students work in groups of three to four and use everyday objects to develop a model or two models of a two-body system to demonstrate their understanding of the relationships between gravitational forces, mass, and relative motion of objects. **Single model:** If students elect to do a single model demonstration, they should explain how a change in the mass of one of the objects in the model would affect the magnitude of the force and the motion of the smaller object. • Sample Model: Two students hold the ends of a jump rope. The less massive student sits on a gym scooter. A third student gives a push to the student on the scooter to get them started, but the orbit is maintained by pulling on the jump rope. Students then describe how the forces and motion would be different if, say, a kindergartener was on the scooter instead. **Dual model:** If students elect to do a dual model demonstration, they should explain how the sets of objects differ and how the differences affect the magnitude of the force and the motion of the smaller object. • Sample Model: One large and one small ball of clay are attached by a length of a string. A student then holds the large ball of clay in one hand and uses it to swing the smaller ball in a circular orbit. The demonstration is then repeated with two similarly sized balls of clay, and students narrate the differences in forces and motion. To vary the complexity and student expectations related to the development of the models, the following aspects of model development can be varied: • Provide preselected objects to students who require additional assistance, while challenging others to think of their own sets of objects. • Give every group a different set of preselected objects. • Ask groups who need an additional challenge to consider how the model would change if the two objects were, say binary stars (roughly equal in mass). **Using Gravity to Find Alien Worlds** • 5Es: Elaborate • Estimated Time: 100 minutes • AGs: A16, A17, A18

	In this lesson, students learn about the search for exoplanets and how astronomers can find these star systems using gravity. To begin, introduce students to the idea of exoplanets using the video Exoplanets 101, stopping the video at 1:26. As a class, students discuss their ideas around exoplanets and consider how they might be discovered. (Note: starting at 1:27 the introduction video explains how the planets are discovered. It is important that students do not see this part, because the remainder of the lesson is focused on developing this understanding.) Next, the teacher has students explore the activity on Barycenter described in the problem, materials, and procedure section of Education.com Barycenter. After students have completed this activity, the class should discuss how this might connect with JWST, gravity, and the solar system, and how might this connect with finding planets outside our solar system (exoplanets). Students then read and explore additional resources and information on finding exoplanets using the wobble of stars. Resources: • What Is a Barycenter? | NASA Space Place – NASA Science for Kids [https://spaceplace.nasa.gov/barycenter/en/] • 5 Ways to Find a Planet | Explore – Exoplanet Exploration: Planets Beyond our Solar System (nasa.gov) [https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/] • Exoplanet Exploration: Planets Beyond our Solar System (nasa.gov) [https://exoplanets.nasa.gov/] • Webb Confirms Its First Exoplanet – Exoplanet Exploration: Planets Beyond our Solar System (nasa.gov) [https://exoplanets.nasa.gov/news/1722/webb-confirms-its-first-exoplanet/] • How do you find – and confirm – a planet? 10 things about the search for exoplanets – Exoplanet Exploration: Planets Beyond our Solar System (nasa.gov) [https://exoplanets.nasa.gov/news/1524/how-do-you-find-and-confirm-a-planet-10-things-about-the-search-for-exoplanets/] • Exoplanets 101 | National Geographic - YouTube [https://www.youtube.com/watch?v=EUU0-ZpFoK4&feature=youtu.be]
Instructional Segment 2	
Learning Investigations and Sample Lessons	
Stage 1 Associations **NGSS PEs:**	**Estimated Classroom Time: 600 minutes** **Where Are We?** • 5Es: Engage

MS-ESS1-1 **CCSS:** **SL.8.5** **RST.6-8.7** **WHST.6-8.1** **MP.2** **6.RP.A.1** **7.RP.A.2** **EUs/EQs:** **EU2/EQ2** **EU4/EQ4** **AGs:** **A6** **A7*** **A8** **A9** **A10** **A11**	• Estimated Time: 50 minutes • AGs: A6*, A7*, A8*, A9*, A10*, A11* This lesson is a framing and prior knowledge activity. The lesson begins with a question, "why does the JWST need a sun shield?" This is a review question and is part of the earlier readings. The teacher encourages students to review past materials and asks students to share ideas. The teacher reminds students how, in their reading about JWST, the telescope has a shield to protect it from the sun and heat and light coming from the Earth and moon. The teacher provides students with materials to construct an Earth-sun-moon system model that will help us understand heat and light in our system. Students use what they already know to construct their models. Students should design and build a simple model and then use their model to explain: • Where do heat and light come from in this system? • Why do we have seasons? • Why does the length of day change? • How and why does the sun move in the sky? • What causes a solar eclipse? • What causes a lunar eclipse? • Why does the moon move and change? • Why do we see things repeat? Students should record their thinking for each of these questions and, as we explore and learn, they should revisit their explanatory model and make revisions. **Observing the Sun, Earth, and Moon** • 5Es: Explore • Estimated Time: 250 minutes • AGs: A6, A10, A11 Students explore observational data about the Earth-sun-moon system. Because of the long timespan (one year) of data needed, digital tools and resources such as those listed below can be utilized to gather observations about the motion of objects across the sky. Stellarium provides location/date-specific sky data. Students can change the date/time and location and use the tool to observe the relative motion of the sun and moon. Students can overlay grids and use ground features to help them observe the motion. Using the date/time features provided in the resources, students place the objects "in motion" by increasing the date or month. Students use the set of resources to connect their observations to their knowledge that the Earth orbits the sun and begin surfacing their ideas about how Earth's orbit results in these patterns. In making sense of these observations, students should be scaffolded to build their understanding and skills in using those observations and patterns to reason about how the amount of energy received in a given location changes over time. As students record observations, the teacher asks prompting questions to encourage students to document how the sun and moon change position

North/South and East/West on different days and at different times. The teacher has the class discuss their observations and combine their observations and data into a class set. If students struggle with finding patterns, the teacher could use a "think aloud" to model their thinking as they look at the data and find a pattern. The teacher could then encourage students to do the same and share their thinking aloud.

After looking at the data and discussing the patterns found, students revisit their explanatory model of the Earth-sun-moon system which they first developed in *Where Are We?,* and modify their model to account for these new observations. For example, students may notice that the sun is not always in the same position at the same time each day, and they need to determine how to account for that.

Next, the teacher shares images and timelapse videos related to equinoxes, solstices, sun positions, and the phases of the moon. Here students should make observations and consider how their model does or does not explain the different natural phenomena. If their model cannot explain a phenomenon, they should make revisions.

Resources:

- Total Solar Eclipse (2017) - YouTube [https://www.youtube.com/watch?v=G10m2ZZRH4U]
- SVS - Moon Phase and Libration, 2011 (nasa.gov) [https://svs.gsfc.nasa.gov/3810]
- SVS - NASA Eclipse Imagery [https://svs.gsfc.nasa.gov/12704]
- Sunrise Positions (ametsoc.org) [https://www.ametsoc.org/amsedu/dstreme/extras/sunrises/sunrises.html]
- Seasons (journeynorth.org) [https://journeynorth.org/mclass/fall2012/c110112_1.html]
- Seeing Equinoxes and Solstices from Space - YouTube [https://www.youtube.com/watch?v=FmCJqykN2J0]

As students refine their model to explain these related phenomena, it is important to keep in mind that the models will still have limitations and room for improvement.

Solar Energy and Seasons

- 5Es: Explore
- Estimated Time: 150 minutes
- AGs: A6, A8, A10*

Students analyze daylight hours and surface temperatures to identify patterns that arise from differences in solar radiation for various locations on Earth and use that data and patterns as evidence in their explanation about the sources of the patterns linked by the data. Students use the identified patterns to construct an explanation about how changing amounts of insolation result in the seasonal cycling of temperatures, based on various sources of evidence, potentially including the graphical information/data, their model(s), and their data

	analysis/interpretation, or other resources/products from prior lessons. The assessment focuses on interpreting data collected from cities in the Northern and Southern Hemispheres, preferably representing far north and south, mid-latitudes, and equatorial regions while linking the data to their model and Earth's relative position in its orbit at various times during the year. Resource: • Seasonal Science: Building Claims from Evidence | MyNASAData [https://mynasadata.larc.nasa.gov/lesson-plans/seasonal-science-building-claims-evidence] **Comparing Our Model to Other Models** • 5Es: Evaluate, Elaborate • Estimated Time: 150 minutes • AGs: A6, A8, A9, A10, A11 Having worked on and refined their models, students shift to looking at others' models and make comparisons between others' models and their own. To find other models to consider, students can read core text, explore digital resources curated by the teacher, or conduct their research to find explanations of seasons, eclipses, phases of the moon, and the movement of the sun and moon across the sky. Resources: • Why Do We Have Different Seasons? | California Academy of Sciences - YouTube [https://www.youtube.com/watch?v=WgHmqv_-UbQ] • Our World: Sun's Position - YouTube [https://www.youtube.com/watch?v=D0IrsXkz3I4] • The Earths Tilt - YouTube [https://www.youtube.com/watch?v=e9MU4TouzII] • Moon Phases: Crash Course Astronomy #4 - YouTube [https://www.youtube.com/watch?v=AQ5vty8f9Xc] Students make additional revisions to their model after examining other models and explain any limitations to their model and how it does or does not explain natural phenomena related to the Earth-sun-moon system. Students use this opportunity as a last round of revisions before revisiting the list of questions at the start of the segment.

Instructional Segment 3	
Learning Investigations and Sample Lessons	
Stage 1 Associations **NGSS PEs:** **MS-ESS1-1** **MS-ESS1-2** **CCSS:** **SL.8.5** **RST.6-8.1** **RST.6-8.7** **MP.4** **WHST.6-8.1** **EUs/EQs:** **EU1/EQ1** **EU4/EQ4** **EU5/EQ5** **AGs:** **A5** **A12** **A13** **A14** **A15** **A19**	**Estimated Classroom Time: 700 minutes** **Lumpy Space? Empty Space? Why is Our Universe the Way it is?** • 5Es: Engage; Explore • Estimated Time: 150 minutes • AGs: A13, A14 The teacher engages students' interest in obtaining information about the Milky Way galaxy by displaying a picture of the Milky Way galaxy from the Hubble Space Telescope, a picture of our solar system, and a picture of clusters of galaxies. The teacher poses the question, "What do you notice?," and encourages students to find similarities and differences between these three scales of space. If students do not share an observation about how matter is "clumped" together with large gaps between, the teacher can ask them, "what do you notice about where the 'stuff' is in space?" Students brainstorm ideas about why matter is in these "clumps" at the solar system, galaxy, and cluster scale. Resources: • JWST Galaxy Cluster Image [https://www.nasa.gov/image-feature/goddard/2022/nasa-s-webb-delivers-deepest-infrared-image-of-universe-yet] • JWST Milky Way [https://www.nasa.gov/image-feature/revealing-the-milky-way-s-center] • Solar System [https://voyager.jpl.nasa.gov/galleries/images-voyager-took/solar-system-portrait/] • Additional Photos of Space [https://www.nasa.gov/topics/solarsystem/images/index.html] Then, students brainstorm questions and sub-questions they need to answer to address their main question and to research the structure of our universe. Students should include questions about galaxies in the universe, the Milky Way galaxy, our solar system, and the objects in our solar system including (but not limited to) the James Webb Telescope, Hubble Telescope, the Earth, and the sun. After students have brainstormed a set of questions that they want to answer, the teacher provides students with four to six websites that give information about the Milky Way galaxy (on its own, and in relation to the rest of the universe), our solar system, and objects found in our solar system. Websites should include models of our solar system (e.g., Tour of the Galaxy). Students explore, attempt to answer the questions, and share their findings with peers.

Resources:

- Photographs of the Milky Way from Earth [https://www.insider.com/beautiful-milky-way-galaxy-photos-2020-6#in-elemental-by-miles-morgan-hawaiis-kilauea-volcano-lights-up-the-starry-sky-8]
- Exploring the Milky Way Educator's Guide [https://www.nasa.gov/stem-ed-resources/exploring-milky-way.html]
- Tour of the Galaxy (video of Earth's place in the Milky Way galaxy) [https://aptv.pbslearningmedia.org/resource/buac18-35-sci-ess-tourofgalaxy/tour-of-the-galaxy/]
- National Geographic Kids article on The Milky Way Galaxy [https://kids.nationalgeographic.com/space/article/milky-way]
- Pictures of the Milky Way Galaxy from Earth (with text) [https://www.discovery.com/science/Picture-of-the-Entire-Milky-Way]
- Informational text about the Milky Way Galaxy [https://www.britannica.com/place/Milky-Way-Galaxy]
- Modeling the Structure of the Solar System [https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-structure-of-the-solar-system/]
- Interactive Model of the Solar System [https://www.solarsystemscope.com/]
- Map a Solar System [https://contrib.pbslearningmedia.org/WGBH/buac18/buac18-int-mapmodelss/index.html]

Gravity Pulls Us All Together

- 5Es: Engage, Explore
- Estimated Time: 150 minutes
- AGs: A5, A14, A15*, A19*
- Sample Lesson

In this lesson, students explore a nebula to understand the uneven distribution of mass/matter within the cloud and then watch a simulation to see how these gas clouds collapse into a solar system.

To start, the teacher introduces students to a nebula by using animation or simulation. For example: NASA video simulation takes viewers on a journey through the Orion Nebula - SpaceFlight Insider provides a "tour" of a nebula by NASA. Students document what they are observing and wondering as well as draw pictures of what they see. Students/the class may want to watch the animation several times. Students consider what forces would be causing what they observe happening and then turn and talk with a classmate about their ideas before discussing them as a class.

In the nebula, we can see stars, gases, rocky objects, and protostars. The NASA video is a static animation. We cannot watch a nebula condense and form. To see how nebula condense and form into stars and solar systems, students watch another animation, Star Formation in a Massive Giant Molecular Cloud. This animation presents the evolution of a nebula over thousands of years, and the animator zooms into points on the simulation where students can see how gravity causes the cloud to not only condense but also to rotate. This rotation will lead to the next lesson on the formation of these systems into disk shapes. The animation, A Virtual Gas Cloud Collapses Into a Smattering of New Stars, provides another simulation; this one remains zoomed out and proceeds over several millions of years. The teacher provides students with an opportunity to reflect on their observations and consider what is causing these clouds to collapse. In addition to discussing gravity as a driving force of the collapse of a nebula into stars, the teacher uses questioning to ask students to consider the orange jets, starting around 0:20 sec into the video: "What do you think these orange areas are? Why do they appear suddenly? What do you think is causing them? Encourage students to reflect on the prior unit and the concepts of kinetic energy and energy conservation.

In the next section, the teacher supports students as they read more about stellar formation and explore materials. Students read about the formation of stars through gravity, for example: How Do Stars Form? · Frontiers for Young Minds (frontiersin.org). As they read, students organize the content using a concept map or another reading strategy that supports developing informational text skills.

Then, students revisit their sub-questions and identify those that they can answer, those that need more information, and any new questions that have emerged because of their learning.

Sample Lesson: "Gravity Pulls Us All Together"

Rotating Discs in Space

- 5Es: Explore, Elaborate
- Estimated Time: 100 min
- AGs: A12, A19

The teacher returns to the images of the galaxy cluster, the Milky Way, and the solar system from the first lesson of Segment 3 (i.e., *Lumpy Space? Empty Space? Why is Our Universe the Way it is?*). The teacher asks students to consider, "If gravity pulls everything together, why don't we fall into the sun or the center of the galaxy? Why do we stay where we are around the sun and around the center of the galaxy?" Students can share their thoughts or document their initial ideas in their science notebooks. Next, the teacher draws students' attention either back to the observation that both the galaxy, the solar system, and the other galaxies are all disc-shaped, or if they did not see it, the teacher draws their attention to this feature by posing the question, "Why is the disc shape so common?" Some students may notice that not all galaxies are spiral/disc-shaped, which will come up as students explore the topic. The teacher can also replay one of the animations of the nebula from the day before.

(These space features are shaped like discs because of the conservation of angular momentum, which occurs when the clouds of gas/dust collapse due to gravity while rotating. In this lesson, students explore hands-on demonstrations around

	angular momentum to see why disc formation is so common and then explore simulations where they see the interactions of galaxies to see how disc-shaped galaxies lead to other shapes when they collide. All these processes are driven by the attractive force of gravity. Angular momentum is a concept that is above grade level and is not fully covered by this lesson. The teacher may want to include additional resources around angular momentum for advanced students.) The teacher poses this question to students: "What do you think riding a bike has to do with galaxy formation?" After students share their responses, the teacher provides students with opportunities to experience the physical feelings of rotational resistance to change using a variety of tools such as: • Bicycle Wheel Gyro [https://www.exploratorium.edu/snacks/bicycle-wheel-gyro] • Momentum Machine [https://www.exploratorium.edu/snacks/momentum-machine] • Hoberman Sphere [https://thekidshouldseethis.com/post/angular-momentum-demonstration-video] • Gyroscope [https://www.sciencekids.co.nz/videos/physics/gyroscope.html] Ideally, all students experience these demonstrations/activities, but the teacher can substitute with videos or whole class demonstrations if necessary. Feeling the inertia when rotating will support students with this complex and not necessarily intuitive topic. The teacher uses questioning and encourages reflection to support students in seeing that objects rotating want to keep rotating, they don't want to change orientation, and that if they get smaller (the radius decreases), their speed increases. Next students should watch the video How do the Planets Stay in Orbit Around the Sun? - YouTube. Students should revisit the initial questions posed by the teacher, "If gravity pulls everything together, why don't we fall into the sun? Or the center of the galaxy? Why do we stay where we are around the sun and around the center of the galaxy?" Using evidence from their physical demonstrations and their research students write an explanation connecting ideas from this experience with learning from *Analyze and Interpret Data on Gravitational Forces and Relative Mass of Objects* and *Gravity Pulls Us All Together.* **Modeling Earth, Our Solar System, and Our Galaxy: "Around We Go"** • 5Es: Explore; Explain • Estimated Time: 150 minutes • AGs: A12, A13, A14 Students have explored the why behind the structure of the universe, and now they switch to the "what" of the structure of our solar system, galaxy, and the

	universe as a whole. This activity is an opportunity as well to do the jigsaw; the teacher could either present students with a list of potential topics to research (stars (the different types), individual solar system planets, exoplanets, comets, asteroids, satellites, nebula, etc.) or students can be tasked with conducting their research and finding their objects. If students jigsaw the topics, they can individually do a deep dive into an object, share that learning with their peers, and then document the information their peers have shared to use later. Resources: • Our Solar System [https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/] • Modeling the Structure of the Solar System [https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-structure-of-the-solar-system/] • Interactive Model of the Solar System [https://www.solarsystemscope.com/] • Map a Solar System [https://contrib.pbslearningmedia.org/WGBH/buac18/buac18-int-mapmodelss/index.html] • Exploring the Milky Way Educator’s Guide [https://www.nasa.gov/stem-ed-resources/exploring-milky-way.html] • Early Models of the Solar System [https://spark.iop.org/early-ideas-about-solar-system#gref] • The Solar System [https://www.space.com/56-our-solar-system-facts-formation-and-discovery.html] • Solar System Facts [https://nineplanets.org/solar-system/] • Encyclopedia Britannica Solar System [https://www.britannica.com/science/solar-system] • Solar System Britannica Kids [https://kids.britannica.com/students/article/solar-system/277129] • Books ○ *The Milky Way and Beyond: Stars, Nebulae, and Other Galaxies* by Erik Gregersen ○ *The Mysteries of the Universe: Discover the best-kept secrets of space* by Will Gater ○ *The Universe (Lonely Planet)* by Lonely Planet (Author) ○ *The Milky Way (Exploring Space)* by Martha E. H. Rustad

Science
Grade: 8 Unit: 2
42 days of instruction

Accessibility and Differentiation for Diverse Learners
"Universal Design for Learning (UDL) is a framework to improve and optimize teaching and learning for all people based on scientific insights into how humans learn" (CAST, 2022). Taking time to reflect on prior instruction when planning for accessible, differentiated, and culturally responsive instruction for diverse learners and culturally diverse classrooms serves to identify ways to improve future instructional practices. The UDL Guidelines provide a framework for this reflection. The guidelines include three principles, Multiple Means of Engagement, Multiple Means of Representation, and Multiple Means of Action & Expression as ways to focus on variety and flexibility in instructional practices. By examining instruction and instructional materials through the lens of each of these principles, we can identify and thus reduce or remove barriers to diverse learners. Providing Multiple Means of Engagement (e.g., allowing choices, authentic scenarios, varying demands, and clear goals), broadens the opportunities for gaining and sustaining students' interest and cognitive engagement in learning the content. Providing Multiple Means of Representation (e.g., variety of presentation modes, clarifying vocabulary, activating background knowledge) allows students to receive and comprehend the content. Providing Multiple Means of Action & Expression (e.g., a variety of methods to respond to instruction, and a variety of ways to interact with the instructional materials) helps students to use their strengths and abilities to access the instructional materials and express what they understand. Accommodations typically reserved for students receiving special education, students who have a 504 plan, and English Learners can be made available to all students using the UDL principles, thus allowing all students to benefit from the accommodations. The SIPS Grade 8 Unit 2 Instructional Framework Differentiation Strategies and Resources support educators' intentional planning of accessible, differentiated, and culturally responsive instruction for all students aligned to the specific performance expectations in focus for this unit.
Core Text Connections
• What is the James Webb Space Telescope? (NASA) [https://spaceplace.nasa.gov/james-webb-space-telescope/en/] • Unheard Voices, Part 1: The Astronomy of Many Cultures. A Resource Guide by Andrew Fraknoi [https://multiverse.ssl.berkeley.edu/Portals/0/Documents/Unheard%20Voices%20Resource%20Guides/Multicultural_Astronomy_updated20160812.pdf?ver=2016-09-14-130655-903] • Unheard Voice, Part 2: Women in Astronomy. A Resource Guide by Andrew Fraknoi [https://multiverse.ssl.berkeley.edu/Portals/0/Documents/Unheard%20Voices%20Resource%20Guides/Unheard%20Voices%20Women%202021%20To%20Print.pdf?ver=2021-11-01-103527-957] • Solar System Data: (NASA JPL) [https://ssd.jpl.nasa.gov/planets/phys_par.html] • Moons of Saturn: [https://www.britannica.com/place/Saturn-planet/Moons] • Moons of Jupiter: [https://airandspace.si.edu/exhibitions/exploring-the-planets/online/solar-system/jupiter/moons.cfm] • The Mysterious Force of Gravity Explained (YouTube)

[https://youtu.be/ybxSgIBbBh8]

- NASA, What is a Barycenter
  [https://spaceplace.nasa.gov/barycenter/en/]
- 5 Ways to Find a Planet
  [https://exoplanets.nasa.gov/alien-worlds/ways-to-find-a-planet/]
- Exoplanet Exploration
  [https://exoplanets.nasa.gov]
- Webb Confirms Its First Exoplanet
  [https://exoplanets.nasa.gov/news/1722/webb-confirms-its-first-exoplanet/]
- How do you find—and confirm—a planet?
  [https://exoplanets.nasa.gov/news/1524/how-do-you-find-and-confirm-a-planet-10-things-about-the-search-for-exoplanets/]
- Vox: How to Find a Planet You Can't See
  [https://youtu.be/STsI6IbPbGQ]
- Why Do We Have Different Seasons? | California Academy of Sciences
  [https://www.youtube.com/watch?v=WgHmqv_-UbQ]
- Our World: Sun's Position
  [https://www.youtube.com/watch?v=D0IrsXkz3I4]
- The Earth's Tilt
  [https://www.youtube.com/watch?v=e9MU4TouzII]
- Moon Phases: Crash Course Astronomy
  [https://youtu.be/AQ5vty8f9Xc]
- Our Solar System
  [https://solarsystem.nasa.gov/solar-system/our-solar-system/overview/]
- Modeling the Structure of the Solar System
  [https://www.jpl.nasa.gov/edu/teach/activity/modeling-the-structure-of-the-solar-system/]
- Early Models of the Solar System
  [https://spark.iop.org/early-ideas-about-solar-system#gref]
- The Solar System
  [https://www.space.com/16080-solar-system-planets.html]
- Solar System Facts
  [https://nineplanets.org/solar-system/]
- Encyclopedia Britannica Solar System
  [https://www.britannica.com/science/solar-system]

Books

- *The Milky Way and Beyond: Stars, Nebulae, and Other Galaxies* by Erik Gregersen
- *The Mysteries of the Universe: Discover the best-kept secrets of space* by Will Gater
- *The Universe (Lonely Planet)* by Lonely Planet (Author)
- *The Milky Way (Exploring Space)* by Martha E. H. Rustad
- Native Science (Chapter on Astronomy) by Gregory Cajete
  - Note: This book has many different chapters on the different Indigenous Ways of Knowing the world, with a chapter on astronomy.
- How Are Stars Formed? (How Stuff Works) [https://science.howstuffworks.com/how-are-stars-formed.htm]
- The Formation of Stars (NASA) [https://www.nasa.gov/multimedia/imagegallery/image_feature_1444.html]
- Star Formation and Evolution (Britannica) [https://www.britannica.com/science/star-astronomy/Star-formation-and-evolution]
- Planet Formation (Harvard & Smithsonian) [https://pweb.cfa.harvard.edu/research/topic/planet-formation]
- Star Formation (Harvard & Smithsonian) [https://pweb.cfa.harvard.edu/research/topic/star-formation]
- Universe, What We Study, Stars (NASA) [https://science.nasa.gov/astrophysics/focus-areas/how-do-stars-form-and-evolve]
- How Do Stars Form? (Frontiers for Young Minds) [https://kids.frontiersin.org/articles/10.3389/frym.2019.00092]
- Can Moons Have Moons? (Universe Today) [https://www.universetoday.com/109666/can-moons-have-moons/]

Instructional Resources

- Claim-Evidence-Reasoning Resources
  - Using the Claim, Evidence, Reasoning (CER) Framework in the Classroom | Edutopia [https://www.edutopia.org/blog/science-inquiry-claim-evidence-reasoning-eric-brunsellasoning (CER) Framework in the Classroom | Edutopia]
  - CER.pdf (dvusd.org) [https://www.dvusd.org/cms/lib/AZ01901092/Centricity/Domain/5849/CER.pdf]
  - CER Paragraph Format with EXAMPLE [https://docs.google.com/document/d/14xfnFV1I97bdJzMa9avCIAz7M65mcjdxmI2JIco90a8/edit#!]
- Argumentation Resources
  - Microsoft Word - Argumentation Instructional Strategies .docx (sciencepracticesleadership.com)

[https://www.sciencepracticesleadership.com/uploads/1/6/8/7/1687518/argumentation_instructional_strategies_.pdf]
  - PD Playlist: Incorporating Scientific Argumentation into Your Classroom : StemTeachingTools (en-US)
    [https://stemteachingtools.org/pd/playlist-argumentation]
  - Scientific Argument - Home (weebly.com)
    [http://sciencearguments.weebly.com/]
  - Making a Claim: Teaching Students Argument Writing Through Close Reading - We Are Teachers
    [https://www.weareteachers.com/making-a-claim-teaching-students-argument-writing-through-close-reading/]
- Resources for Peer Review/Feedback/Critique
  - 7 Critiques You Can Use in Your Classroom Today! - The Art of Education University
    [https://theartofeducation.edu/2014/10/09/7-critiques-you-can-use-in-your-classroom-today/]
  - How Students Critiquing One Another's Work Raises The Quality Bar | KQED
    [https://www.kqed.org/mindshift/47199/how-students-critiquing-one-anothers-work-raises-the-quality-bar]
  - Peer Review Done Right | Edutopia
    [https://www.edutopia.org/article/peer-review-done-right]
  - Peer assessment | Center for Teaching Innovation (cornell.edu)
    [https://teaching.cornell.edu/teaching-resources/assessment-evaluation/peer-assessment]
- Obtaining, Evaluating, and Communicating Information
  - Instructional Strategies for Practicing Obtaining Information
    [https://www.sciencepracticesleadership.com/uploads/1/6/8/7/1687518/information_instructional_strategies.pdf]
- Misconceptions
  - Common Misconceptions About Our Solar System
    [https://www.generationgenius.com/wp-content/uploads/2020/07/GG-Solar-System-TG.pdf]