UNIT 2

Travelling through Space

What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?

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Stanford NGSS Integrated Curriculum: An Exploration of a Multidimensional World

Unit 2: Travelling Through Space

Essential Question: What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?

Total Number of Instructional Days: 31.5 – 34.5

Lift-Off Task: Our Solar System	**Task 1:** A Sun-Earth-Moon Model	**Task 2:** A Solar System Model	**Task 3:** Gravity in the Galaxies	**Task 4:** Invisible Forces

Connect to the Culminating Project using the Project Organizer

Group Culminating Project:
Create a solar system model and propose a route for a new telescope through space.

Individual Culminating Project
Create a presentation to pitch your proposed route for the new telescope.

Unit 2 Pop-Out
How Power Influences Science
(*Implement after project*)

Storyline for Unit 2

In this unit, students are exploring both physics and space science concepts, from electromagnetism to the Sun-Earth-Moon system. This unit's project combines both of these disciplines, as students learn everything they can about the solar system and various forces to help them chart a route for a new telescope through space. The Lift-Off Task asks students to draw off their own prior knowledge to generate questions around the phenomenon of our solar system—questions that they will continue to explore throughout this unit.

As students pool their prior knowledge in the Lift-Off Task, they will likely create a list of different things they might find in a solar system. However, in order to chart a telescope route through the solar system, it is not enough to just know what is there—they must find out where things are and how they are laid out within the system. The best way to visualize such a large system is to create a model. In Task 1, students will practice modeling with the smaller sub-system of the Sun-Earth-Moon system. In doing so, they will discover explanations for a lot of the phenomena they experience on Earth.

In Task 2, students use the modeling skills they practiced in the previous task to develop a model of the entire solar system. Unlike in the last task, however, students now focus on the scale aspect of developing models. By analyzing data on the scale properties of objects in the solar system, they will find that while the solar system is huge, they can use math to model it on a smaller scale. This class model they create provides the perfect stage within which to plot their telescope route.

At this point, students have a model of the solar system so they can begin to visualize where their telescope route may be. However, the parts of the solar system are not stationary…they move! In Task 3, students examine what factors affect the motion of objects within the solar system—specifically gravity. Using prior knowledge of gravity from Unit 1 and new simulation models, students build an understanding that gravity helped to create the solar system and gravity continues to maintain its structure and motion.

While gravity is one invisible force to consider, magnetism is another invisible force that must be understood to plot a safe telescope route. In Task 4, students conduct investigations to prove that magnetic fields do exist and can explain various phenomena that they experience. They will then use this information to create a strong magnetic field that protects their telescope as it travels through space, as well as predict how the telescope will behave in space due to its magnetic field.

By the end of the unit, groups will have collectively constructed a complete class-wide solar system model. Once students are complete with all tasks, each group makes an informed decision on the route they think the new telescope should take and how they will protect it as it moves through space. These routes can be presented within the class-wide model. Lastly, each student will individually create a presentation that pitches their group's route, describing the forces and energy both used and encountered on this trip and justifying why their route is the best route.

Three-Dimensional Breakdown of the Performance Expectations

This unit was developed to align with, teach, and assess students' understanding and skills related to these Performance Expectations. Below, we have mapped out the disciplinary core ideas, crosscutting concepts, and science and engineering practices addressed in this unit. Aspects of the dimensions that are not explicitly addressed in this unit are crossed out.

Performance Expectations	Scientific and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.]	**Developing and Using Models** • Develop and use a model to describe phenomena.	**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. **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.	**Patterns** • Patterns can be used to identify cause-and-effect relationships.
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	**Developing and Using Models** • Develop and use a model to describe phenomena.	**ESS1.A: The Universe and Its Stars** • ~~Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.~~ **ESS1.B: Earth and the Solar System** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on	**Systems and System Models** • Models can be used to represent systems and their interactions.

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.*]		them. • The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order to share information with other people, these choices must also be shared.	
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.*]	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**ESS1.B: Earth and the Solar System** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.	**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-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate,	**PS2.B: Types of Interactions** • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]	frame a hypothesis based on observations and scientific principles.	distances between the interacting objects.	
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.	**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.	**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.	**Systems 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-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and is limited to qualitative evidence for the existence of fields.]	**Planning and Carrying Out Investigations** • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	**PS2.B: Types of Interactions** • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes,	**Developing and Using Models** • Develop a model to describe unobservable	**PS3.A: Definitions of Energy** • A system of objects may also contain stored	**Systems and System Models** • Models can be used to represent systems

different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]	mechanisms.	(potential) energy, depending on their relative positions. **PS3.C: Relationships Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

Connections to Common Core Math and ELA Standards:

Over the course of this unit, students will gain knowledge and skills in science, as well as in math and English-language arts. Below we list the Common Core ELA and Math standards for middle school and 8th grade that are relevant to the curriculum tasks in this unit. Within the curriculum, there are opportunities to incorporate components of the following ELA and Math Standards:

Middle School Common Core ELA Standards		Unit Task
Key Ideas and Details	CCSS.ELA-Literacy.RST.6-8.1: Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.	Task 3 Culminating Project
	CCSS.ELA-Literacy. RST. 6-8.3: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	Task 1 Task 4
Integration of Knowledge and Ideas	CCSS.ELA-Literacy.RST.6-8.7: Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).	Task 1 Task 3 Task 4 Culminating Project
Text Types and Purposes	CCSS.ELA-Literacy.WHST.6-8.1: Write arguments focused on discipline content.	Task 3 Culminating Project
Research to Build and Present Knowledge	CCSS.ELA-Literacy.WHST.6-8.7: Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration.	All Unit
Presentation of Knowledge and Ideas	CCSS.ELA-Literacy.SL.8.5: Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest.	Task 1 Task 2 Culminating Project

8th Grade Common Core Math Standards		Unit Task
Mathematical Practice	CCSS.MATH.MP.2: Reason abstractly and quantitatively.	Task 2 Task 3
	CCSS.MATH.MP.4: Model with mathematics.	Task 1 Task 2 Task 3

Connections to English Language Development (ELD) Standards:

We acknowledge that language development is a key component of disciplinary understanding and helps to support more rigorous and equitable outcomes for diverse students. This curriculum thus takes into account both the receptive and productive language demands of the culminating projects and strives to increase accessibility by including scaffolds for language development and pedagogical strategies throughout learning tasks. We aim to support language acquisition through the development of concept maps; utilizing sentence frames; implementing the Critique, Correct, and Clarify technique; employing the Stronger Clearer strategy; and fostering large and small group discussions.

8th Grade Science Unit 2: Travelling Through Space

Unit Overview

The California ELD Standards are comprised of two sections: the standards and a rubric. Outlined below are the standards from Section One that are met within this curriculum. For additional information, please refer to: https://www.pausd.org/sites/default/files/pdf-faqs/attachments/SS_ELD_8.pdf.

Eighth Grade ELD Standards		
Part I: Interacting in Meaningful Ways	A: Collaborative	1.Exchanging information and ideas with others through oral collaborative discussions on a range of social and academic topics
		2. Interacting with others in written English in various communicative forms (print, communicative technology, and multimedia)
		3. Offering and justifying options, negotiating with and persuading others in communicative exchanges
		4. Adapting language choices to various contexts (based on task, purpose, audience, and text type)
	B: Interpretive	5. Listening actively to spoken English in a range of social and academic contexts
		6. Reading closely literary and informational texts and viewing multimedia to determine how meaning is conveyed explicitly and implicitly through language
		7. Evaluating how well writers and speakers use language to support ideas and arguments with details or evidence depending on modality, text type, purpose, audience, topic, and content area
		8. Analyze how writers and speakers use vocabulary and other language resources for specific purposes (to explain, persuade, entertain, etc.) depending on modality, text type, purpose, audience, topic, and content area
	C: Productive	9. Expressing information and ideas in formal oral presentations on academic topics
		10. Writing literary and informational texts to present, describe, and explain ideas and information, using appropriate technology
		11. Justifying own arguments and evaluating others' arguments in writing
		12. Selecting and applying varied and precise vocabulary and other language resources to effectively convey ideas
Part II: Learning About How English Works	A: Structuring Cohesive Texts	1. Understanding text structure
		2. Understanding cohesion
	B: Expanding and Enriching Ideas	3. Using verbs and verb phrases
		4. Using nouns and noun phrases
		5. Modifying to add details
	C: Connecting and Condensing Ideas	6. Connecting ideas
		7. Condensing ideas

Connections to Environmental Awareness:

Over the course of this curriculum, students will explore content related to various environmental principles and concepts that examine the interactions and interdependence of human societies and natural systems. In accordance with the *Education and the Environment Initiative (EEI),* tasks throughout this curriculum explore many of *California's Approved Environmental Principles and Concepts.*

Because the context of this unit revolves around the solar system as a whole and the content mainly emphasizes physics concepts, this unit does not explicitly examine the interactions of humans and natural systems. In later units, we will outline the EEI principles relevant to the unit in this section of the unit overview.

8th Grade Science Unit 2: Travelling Through Space
Teacher Materials List

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Overall Unit – All Tasks
- Unit 2, Task Cards Student Version, Lift-Off and Tasks 1 through 4
- Culminating Project Student Task Card
- Project Organizer
- Projector with Audio (for video or images, whenever needed)

Lift-Off Task (2 days)
Per Student
- Task Card Student Version: Lift-Off
- Post-Its (Optional)
- Task Card Student Version: Culminating Project
- Project Organizer

Per Group
- Poster paper and markers

Whole Class
- Computer and Projector (for images)
- Poster paper and markers
- *See Instructions in Lift-Off for other optional materials to use for the class concept map

Task 1 (6 days)
Per Student
- Task Card Student Version: Task 1
- Project Organizer

Per Station
- Station Cards 1 - 5: two - three per station
- Stations 1, 2, and 5: Computers/tablets (Make sure interactives/videos work)
- Station 3: Styrofoam ball with embedded toothpick and light source (ex: lamp)

Per Group
- Styrofoam Balls of varying size
- Skewers/Toothpicks
- Light sources of varying brightness
- Rubber band
- Marker
- Device with video capabilities

Task 2 (4 days)
Per Student
- Task Card Student Version: Task 2
- Project Organizer

Per Group

- Varied materials to make planet models, such as:
    - Clay
    - Styrofoam spheres
    - Cotton
    - Balloons
    - Construction Paper of different colors
    - Paint and Brushes
- String or Twine
- Rulers (with cm)
- Labels
- Markers

Whole Class

- Light source, such as a standing lamp
- Extension cord, if necessary

Task 3 (5 days)

Per Student

- Task Card Student Version: Task 3
- Project Organizer

Per Pair

- Computers or tablets

Per Group

- Computers or tablets
- Rope or string
- Labels (1 per group)
- Marker

Whole Class

- Computer and Projector, if modeling any of the simulations

Task 4 (4.5 - 6.5 Days)

Per Student

- Task Card Student Version: Task 4
- Project Organizer

Per Station

- Station Cards 1-4 (2 copies for each station)
- Station 1
    - 2 Bar magnets
    - Various objects of different materials, some magnetic and some not
- Station 2
    - Paper clip
    - Piece of Thread
    - Tape
    - Small bar or horseshoe magnet

- Station 3
  - Ziploc Bag
  - 3x5 index cards
  - Iron filings
  - Paper Clip
  - 2 Bar Magnets
- Station 4
  - 5 feet insulated copper wire
  - 6-volt battery
  - D-size battery
  - Large iron nail
  - Paper clips

Per Group
- All materials from the Explore (one set of all materials for each group)

Whole Class
- Projector and Computer

Culminating Project (7-8 days)

Per Group: Solar System Class Model

*There are many different options of materials for students to build the planets for the class-wide scale model. We recommend use of any inexpensive, everyday objects to represent the different-sized planets. Students can even bring in materials from around their house! Some options of materials are below:
- Clay
- Spheres of different sizes (try a craft store for Styrofoam balls, plastic balls, etc.)
- Balloons
- Cotton
- Construction Paper of different colors
- Paint and Brushes
- String or Twine – needed to measure out distances from the sun
- Light Source (Large Lamp) – needed to represent the sun
- Rulers (with cm)
- Optional: magnets if they want to create a telescope model

Per Student: Pitch Presentation of Telescope Route
- Computers with presentation software
- Device with recording capabilities (Ex: phone, tablet, etc)
- Poster Paper
- Markers

Unit 2 Pop-Out (3 days)

Per Student
- Student Version: Unit 2 Pop-Out
- Unit 2, Pop-Out Scenario

Per Group

8th Grade Science Unit 2: Travelling Through Space

Teacher Materials List

- Computer
- Video Camera

8th Grade Science Unit 2: Travelling Through Space
Building on Prior Knowledge

While Unit 2 has a space context that is similar to Unit 1 and continues to explore some physical science concepts, it more heavily focuses on concepts related to Earth's place in the universe. In doing so, students move away from contact forces and instead focus on the non-contact forces that might affect a telescope's route through the solar system, which serves as the culminating project for this unit. As students progress through this unit, they will form a more complex picture of the solar system as a whole, which they will use to explain some of the everyday phenomena they experience.

The integrated model requires students to access and use a wide range of ideas from prior grades. This content knowledge spans five different Disciplinary Core Ideas: ESS1.A. The Universe and Its Stars, ESS1.B. Earth and the Solar System, PS2.B. Types of Interactions, PS3.A. Definitions of Energy, and PS3.C. Relationships Between Energy and Forces.

As students explore these core ideas, they build on their skills in the following science and engineering practices: Asking Questions and Defining Problems, Developing and Using Models, Planning and Carrying Out Investigations, Analyzing and Interpreting Data, and Engaging in Arguments From Evidence. In addition to science and engineering practices, students also continue to build on their knowledge of the following crosscutting concepts: Patterns; Cause and Effect; Scale, Proportion, and Quantity; and Systems and System Models.

*This summary is based on information found in the NGSS Framework.

K-8 Progression of Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts for Unit 2

Disciplinary Core Ideas	K-2	3-5	6-8
ESS1.A The Universe and Its Stars	Patterns of the motion of the sun, moon, and stars in the sky can be observed, described, and predicted.	The sun is a star that appears larger and brighter than other stars because it is closer. Stars range greatly in their distance from Earth.	Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted and explained with models. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.
ESS1.B Earth and the Solar System	Seasonal patterns of sunrise and sunset can be observed, described, and predicted.	The orbits of Earth around the sun and of the moon around Earth, together with the rotation of Earth about an axis between its North and South poles, cause observable patterns. These include day and night; daily changes in the length and direction of shadows; and different positions of the sun, moon, and stars at different times of the day, month, and year.	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. 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. The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.

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Building on Prior Knowledge

PS2.B Types of Interactions	N/A (in relation to non-contact types of interactions)	Electric, and magnetic forces between a pair of objects do not require that the objects be in contact. The sizes of the forces in each situation depend on the properties of the objects and their distances apart and, for forces between two magnets, on their orientation relative to each other. The gravitational force of Earth acting on an object near Earth's surface pulls that object toward the planet's center.	Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. 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. Forces that act at a distance (electric and magnetic) can be explained by fields that extend through space and can be mapped by their effect on a test object (a ball, a charged object, or a magnet, respectively).
PS3.A Definitions of Energy	N/A	Moving objects contain energy. The faster the object moves, the more energy it has. Energy can be moved from place to place by moving objects, or through sound, light, or electrical currents. Energy can be converted from one form to another form.	Motion energy is properly called kinetic energy. A system of objects may also contain stored (potential) energy, depending on their relative positions.
PS3.C Relationships Between Energy and Forces	A bigger push or pull makes things go faster.	When objects collide, the contact forces transfer energy so as to change the objects' motions.	When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.

Science and Engineering Practices	K-2	3-5	6-8
Asking Questions and Defining Problems*	Asking questions and defining problems in K-2 builds on prior experiences and progresses to simple descriptive questions that can be tested. • Ask and/or identify questions that can be answered by an investigation.	Asking questions and defining problems in 3-5 builds on prior experiences and progresses to specifying qualitative relationships. • Identify scientific (testable) and non-scientific (non-testable) questions. • Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.	Asking questions and defining problems in 6-8 builds on prior experiences and progresses to specifying relationships between variables, and clarifying arguments and models. • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

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Building on Prior Knowledge

Developing and Using Models*	Modeling in K-2 builds on prior experiences and progresses to include using and developing models (i.e., diagram, drawing, physical replica, diorama, dramatization, or storyboard) that represent concrete events or design solutions. • Develop and/or use a model to represent amounts, relationships, relative scales (bigger/smaller), and/or patterns in the natural and designed world(s).	Modeling in 3-5 builds on prior experiences and progresses to building and revising simple models and using models to represent events and design solutions. • Develop and/or use models to describe and/or predict phenomena. • Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.	Modeling in 6-8 builds on prior experiences and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. • Develop and use a model to describe phenomena. • Develop a model to describe unobservable mechanisms.
Planning and Carrying Out Investigations	Planning and carrying out investigations to answer questions or test solutions to problems in K-2 builds on prior experiences and progresses to simple investigations, based on fair tests, which provide data to support explanations or design solutions. • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence to answer a question.	Planning and carrying out investigations to answer questions or test solutions to problems in 3-5 builds on prior experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions. • Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.	Planning and carrying out investigations to answer questions or test solutions to problems in 6-8 builds on prior experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions. • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.
Analyzing and Interpreting Data	Analyzing data in K-2 builds on prior experiences and progresses to collecting, recording, and sharing observations. • N/A	Analyzing data in 3-5 builds on prior experiences and progresses to introducing quantitative approaches to collecting data and conducting multiple trials of qualitative observations. When possible and feasible, digital tools should be used. • Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.	Analyzing data in 6-8 builds on prior experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. • Analyze and interpret data to determine similarities and differences in findings.

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Engaging in Argument from Evidence*	Engaging in argument from evidence in K-2 builds on prior experiences and progresses to comparing ideas and representations about the natural and designed world(s). • Construct an argument with evidence to support a claim.	Engaging in argument from evidence in 3-5 builds on prior experiences and progresses to critiquing the scientific explanations or solutions proposed by peers by citing relevant evidence about the natural and designed world(s). • Construct and/or support an argument with evidence, data, and/or a model. • Use data to evaluate claims about cause and effect.	Engaging in argument from evidence in 6-8 builds on prior experiences and progresses to constructing a convincing argument that supports or refutes claims for either explanations or solutions about the natural and designed world(s). • 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.

*These SEPs are summatively assessed using the Culminating Project.

Crosscutting Concepts	K-2	3-5	6-8
Patterns*	Students recognize that patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence. • Patterns in the natural and human designed world can be observed, used to describe phenomena, and used as evidence.	Students identify similarities and differences in order to sort and classify natural objects and designed products. They identify patterns related to time, including simple rates of change and cycles, and to use these patterns to make predictions. • Patterns of change can be used to make predictions. • Patterns can be used as evidence to support an explanation.	Students recognize that macroscopic patterns are related to the nature of microscopic and atomic-level structure. They identify patterns in rates of change and other numerical relationships that provide information about natural and human designed systems. They use patterns to identify cause and effect relationships, and use graphs and charts to identify patterns in data. • Patterns can be used to identify cause-and-effect relationships.
Cause and Effect*	Students learn that events have causes that generate observable patterns. They design simple tests to gather evidence to support or refute their own ideas about causes. • Events have causes that generate observable patterns.	Students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause and effect relationship. • Cause and effect relationships are routinely identified, tested, and used to explain change.	Students classify relationships as causal or correlational, and recognize that correlation does not necessarily imply causation. They use cause and effect relationships to predict phenomena in natural or designed systems. They also understand that phenomena may have more than one cause, and some cause and effect relationships in systems can only be described using probability. • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Scale, Proportion, and Quantity*	Students use relative scales (e.g., bigger and smaller; hotter and colder; faster and slower) to describe objects. They use standard units to measure length. • Relative scales allow objects and events to be compared and described (e.g., bigger and smaller; hotter and colder; faster and slower).	Students recognize natural objects and observable phenomena exist from the very small to the immensely large. They use standard units to measure and describe physical quantities such as weight, time, temperature, and volume. • Natural objects and/or observable phenomena exist from the very small to the immensely large or from very short to very long time periods.	Students observe time, space, and energy phenomena at various scales using models to study systems that are too large or too small. They understand phenomena observed at one scale may not be observable at another scale, and the function of natural and designed systems may change with scale. They use proportional relationships (e.g., speed as the ratio of distance traveled to time taken) to gather information about the magnitude of properties and processes. They represent scientific relationships through the use of algebraic expressions and equations. • Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.
Systems and System Models*	Students understand objects and organisms can be described in terms of their parts; and systems in the natural and designed world have parts that work together. • Objects and organisms can be described in terms of their parts. • Systems in the natural and designed world have parts that work together.	Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions. • A system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. • A system can be described in terms of its components and their interactions.	Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study. • Models can be used to represent systems and their interactions. • Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

*These CCCs are summatively assessed using the Culminating Project.

Progression of Knowledge from Kindergarten – 8th Grade

ESS1.A. The Universe and Its Stars: As with most of the DCIs, students begin their experience in kindergarten – second grade with an experience of the relevant phenomena—in this case, the appearance of the sun, moon, and stars. At this level, students are making observations to describe patterns that they will be able to utilize again in this eighth grade unit. In third – fifth grade, students begin to investigate the why, or the science behind, one of these phenomena: why does the sun and some stars appear brighter than other stars? Here, students are connecting mere observations to the scientific reason behind them, a process they will continue in this eighth grade unit. By the time they reach this unit, they will be ready to develop a model of the Earth-sun-moon system and use it to explain the phenomena they first analyzed as first graders, like the apparent motion of the sun, the moon, and stars. Depending on the phenomena being investigated and the practice used to investigate it at the given grade level, the crosscutting concepts range from Patterns to Scale, Proportion, and Quantity to Systems and System Models. Similarly, the science and engineering practices range from Analyzing and Interpreting Data to Engaging in Argument From Evidence to Developing and Using Models.

The following is the progression of the Performance Expectations for this DCI:

1-ESS1-1. Use observations of the sun, moon, and stars to describe patterns that can be predicted.

5-ESS1-1. Support an argument that differences in the apparent brightness of the sun compared to other stars is due to their relative distances from Earth.

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

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

<u>ESS1.B. Earth and the Solar System</u>: While this DCI is very similar to the DCI above, you will notice some key differences. In Kindergarten - second grade, students engage with this DCI at the same grade level as ESS1.A, but rather than making observations of celestial objects in the sky, they focus on the amount of daylight at different times of year. In third – fifth grade, students advance this data collection to include more specific measures, such as length and direction of shadows, day and night, and the seasonal appearance of some stars in the night sky. All of these observations serve as evidence that the Earth orbits around the sun and rotates on its axis once a day, which is what is causing these observable phenomena. By the time students get to this unit, they are able to use this prior knowledge to draw an Earth-sun-moon system model and use it to explain some of the phenomena identified in the paragraph above. However, in this unit, students take it farther than just the Earth-sun-moon system to develop an understanding of the whole solar system as a collection of objects held in orbit around the sun by its gravitational pull on them. To explore this DCI, students focus on the science and engineering practices of Analyzing and Interpreting Data and using that data to Develop and Use Models. Students use the crosscutting concept of Patterns to analyze data, and the crosscutting concepts of Scale, Proportion, and Quantity as well as Systems and System Models when developing their models.

The following is the progression of the Performance Expectations for this DCI:

1-ESS1-2. Make observations at different times of year to relate the amount of daylight to the time of year.

5-ESS1-2. Represent data in graphical displays to reveal patterns of daily changes in length and direction of shadows, day and night, and the seasonal appearance of some stars in they sky.

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

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

PS2.B. Types of Interactions: In Kindergarten - second grade, students are introduced to this DCI within the context of contact forces, which are not explored in this unit (but were explored in Unit 1). In third grade, however, students begin to investigate non-contact forces, such as electric and magnetic forces. By asking questions that lead to investigations and design solutions, students discover that electric and magnetic forces do not require that the objects be in contact. By experimenting with magnets, they will also find that the sizes of these forces can vary depending on the properties of the objects, their distances apart, and even their orientation to each other. This sets the stage for students to continue these investigations in this eighth grade unit, as they not only find evidence that the fields exist but identify factors that can affect the strength of these fields. In fifth grade, students engage with another non-contact force—gravity—by gathering evidence that gravity exerted on objects is directed down towards Earth. In this eighth grade unit, students build off their understanding of gravity from Unit 1 to explore this concept again, but within the context of the whole solar system, rather than just Earth. They will find that gravity is attractive with other objects of large mass, like other planets. At all grade levels, students are utilizing the crosscutting concept of Cause and Effect as they engage with this DCI through different practices like Asking Questions and Defining Problems, Engaging in Argument From Evidence, and Planning and Carrying Out Investigations.

The following is the progression of the Performance Expectations for this DCI:

3-PS2-2. Ask questions to determine cause and effect relationships of electric or magnetic interactions between two objects not in contact with each other.

3-PS2-3. Define a simple design problem that can be solved by applying scientific ideas about magnets.

5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces.

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

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact.

PS3.A. Definitions of Energy: Students do not engage with this DCI until the fourth grade. In third – fifth grade, students begin to connect motion with energy, asking questions like: What is energy and how is it related to motion? How is energy transferred? Because energy is a difficult concept for students to conceptualize at this age, these performance expectations deal mostly with experiential knowledge. By the end of this grade band, students will understand that the faster a given object is moving, the more energy it possesses, and that objects can transfer energy not just through collisions (as they studied in Unit 1), but also by sound, light, heat, and electric currents. In the first unit of eighth grade, students gave motion energy its proper name as kinetic energy and explored its relationship to the mass and speed of the object in question. This is crucial to this eighth grade unit, as students take their understanding of kinetic energy and apply it to other concepts, such as potential energy and how this is affected by the arrangement of objects interacting at a distance. At the fourth grade level, students focused on the crosscutting concept of Energy and Matter as they conducted investigations to gather evidence for explanations of these phenomena. However, by this unit, students move towards Developing Models to explain the phenomenon as a system.

The following is the progression of the Performance Expectations for this DCI:

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

4-PS3-2. Make observations to provide evidence that energy can be transferred from place to place by sound, light, heat, and electric currents.

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

PS3.C. Relationships Between Energy and Forces: In Kindergarten - second grade, students are not explicitly introduced to this DCI, but it does serve as the secondary DCI for K-PS2-1 below. This PE allows students to establish a basic relationship between force and energy by experiencing that a bigger push or pull makes things speed up or slow down more quickly. While third – fifth grade does access this DCI, it only does so in relation to objects that physically collide, transferring energy that changes the objects' motion. This is a concept explored in Unit 1, but not in this particular eighth grade unit. In this unit, students investigate this relationship between force and energy in a way that is far more difficult to visualize. Here, students consider how when two magnetic objects interact from a distance, the magnetic potential energy can result in kinetic energy of that object. To demonstrate this, students develop and use a model through the lens of Systems and System Models.

The following is the progression of the Performance Expectations for this DCI:

K-PS2-1. Plan and conduct an investigation to compare the effects of different strengths or different directions of pushes and pulls on the motion of an object.

4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide.

MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

8^{th} Grade Science Unit 2: Travelling Through Space
Culminating Project

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction

Telescopes have played a huge role in our history, opening our eyes to the mysteries of the universe. Telescopes on Earth have revealed new planets, stars, and asteroids and much, much more. However, modern telescopes, like the Hubble Space Telescope, take our technology a step further by launching the actual telescopes into space to study objects up close and look even farther out in the universe.

For this culminating project, students are going to consider the launch of a new telescope, which NASA hopes to launch into the solar system next year. What things will need to be considered to complete this mission efficiently and safely? Throughout the unit, each group will contribute to a class-wide model of our solar system—the phenomenon they were introduced to in the Lift-Off task. Using this model and new scientific concepts they learn, each group will then make an informed decision on the route they think the new telescope should take and how they will protect it as it moves through space. Once all groups have shown their routes within the class model, they will individually create a presentation that pitches their group's route, describing the forces and energy both used and encountered on this trip and justifying why their route is the best route. The format of this presentation will be up to them (Prezi with a script, Powerpoint with a script, video, videotaped poster presentation, etc.)

3-Dimensional Assessment

Disciplinary Core Ideas

ESS1.A: The Universe and Its Stars
- Patterns of the apparent motion of celestial bodies can be described and explained with models.

ESS1.B: Earth and the Solar System
- The solar system consists of the sun and a collection of objects held in orbit around it by gravity.
- The solar system was formed from a disk of dust and gas, drawn together by gravity.
- A model of the sun-earth-moon system can explain eclipses and seasons.

PS2.B: Types of Interactions
- Electric and magnetic forces can be attractive or repulsive, and their sizes depend on factors.
- Gravitational forces are attractive and vary depending on the mass of the objects.
- Forces that act at a distance can be explained by fields.

PS3.A: Definitions of Energy
- A system of objects may contain stored (potential) energy, depending on relative position.

PS3.C: Relationship Between Energy and Forces
- When two objects interact, each one exerts a force on the other that can cause energy to be transferred.

Science and Engineering Practices

Asking Questions
- Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.

Developing and Using Models
- Develop and use a model to describe phenomena.
- Develop a model to describe unobservable mechanisms.

Engaging in Arguments 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.

Crosscutting Concepts

Cause and Effect
- Cause and effect relationships may be used to predict phenomena in natural or designed systems.

Patterns
- Patterns can be used to identify cause-and-effect relationships.

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.

Systems and System Models
- Models can be used to represent systems and their interactions.
- Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

8th Grade Science Unit 2: Travelling Through Space
Culminating Project

Time Needed (Based on 45-Minute Periods)
7-8 days at end of unit
- Group Project: 2-3 periods (includes 1 presentation day)
- Individual Project: 5 periods
  - First draft: 3 periods
  - Feedback: 1 period
  - Revision: 1 period

Materials
Group Project
*There are many different options of materials for students to build the planets for the class-wide scale model. We recommend use of any cheap, everyday objects to represent the different-sized planets. Students can even bring in materials from around their house! Some options of materials are below:
- Clay
- Spheres of different sizes (try a craft store for Styrofoam balls, plastic balls, etc.)
- Balloons
- Cotton
- Construction Paper of different colors
- Paint and Brushes
- String or Twine – needed to measure out distances from the sun
- Light Source (Large Lamp) – needed to represent the sun
- Rulers (with cm)
- Optional: magnets if they want to create a telescope model

Individual Project
- Computers with presentation software
- Device with recording capabilities (Ex: phone, tablet, etc)
- Poster Paper
- Markers

Instructions for the Culminating Project

1. Introduce the Culminating Project at the end of the Lift-Off task, including both the group and individual components outlined in the Challenge.

2. Read over the Culminating Project Task Card with the students. We recommend reviewing only the Challenge and Group Project Criteria for Success with students at this time in order to not overwhelm students with information.
   - Take questions for clarification.

3. Give a brief overview of the Background on the new telescope, especially emphasizing the image and last paragraph.
   - This will give students detail on where the new telescope will need to be launched.

4. Remind students that as they go through the Project Organizer, they will be planning pieces of their model and route and recording scientific concepts they will likely need for their individual project.

However, there is nothing wrong with going back and changing their ideas over the course of the unit. The students won't fully design their route until the end of the unit, so change during the processing time is acceptable and often experienced.

5. Make sure the students fill out the Project Organizer after each task, which will help students think about how information about the solar system and non-contact forces can help them plan their telescope route. This process allows students to both apply and document relevant scientific concepts as they move through the unit. This will inform both their group and individual projects.
    - We recommend that students complete the Project Organizer individually. They might discuss ideas first as a group, but should then respond individually. This allows students time to process concepts on their own and generate their own ideas, which can be used later when it comes to developing their group project.

6. The table below summarizes how the Project Organizer guides students through developing different components of their model, route, and pitch presentation.

Task	Project Organizer	Group and Individual Culminating Project
Lift Off Our Solar System	• What do you think our solar system consists of?	• Parts of a solar system included in class model. • Pitch presentation shows model of solar system with all parts.
Task 1 A Sun-Earth-Moon Model	• Draw a sketch of a Sun-Earth-Moon model. • Use a model to describe at least two of the phenomena explored in this task. • What are the limitations of the model?	• Pitch presentation has two relevant depictions of a sun-earth-moon model and uses them to describe seasons, lunar phases, eclipses and/or the apparent motion of the sun, moon, or stars.
Task 2 A Solar System Model	• Draw a sketch of the class solar system model. • Explain the scale used for your assigned planet. What data did you use? How does it compare to other planets?	• Group contributes a planet to the class-wide model of the solar system, created to scale. • Pitch presentation identifies data on properties of objects in the solar system that led to the scale of the class model, using their assigned planet as an example.
Task 3 Gravity In The Galaxies	• Draw a potential route for the new telescope. • What is the role of gravity in the solar system? • How can gravity affect the new telescope in space? • How does your understanding of gravity inform why the telescope must stay farther away from some planets, but not others?	• Group shows a potential route for the telescope through the class-wide model of the solar system. • Pitch presentation explains gravity's role in the birth and layout of the solar system. It also shows and describes the group's proposed route for the telescope and justifies their choice by using gravity to explain planets it must stay away from.

Task 4 Invisible Forces	• What evidence is there that magnetic fields exist? • What kinds of factors affect the strength of magnetic fields? What questions did you have to investigate to find out that information? • How might the telescope be affected as it passes planets with different magnetic fields?	• Group recommends the best way to create a protective magnetic field around the telescope and explains how passing by different planets might affect the telescope. • Pitch presentation cites data as evidence that magnetic fields are real and identifies best ways to strengthen one around the telescope. It also contains a model that shows and explains how and why passing by magnetic planets would affect the telescope.

7. After all the learning tasks are completed, and the Project Organizers are completed, groups can start to refine the design of their route and the protection of their telescope.
   - As always, we recommend the use of group roles for Culminating Project work time (See "How to Use This Curriculum" for details). We recommend changing the roles every work day.

8. This project differs from other Culminating Projects in that students are combining class-wide work and group work.
   - The reasoning behind a class-wide solar system model is that space and time constraints would make individual group models very difficult. By creating a class-wide solar system model in which each group is assigned one piece to contribute, students are still responsible for the cognitive load of engaging in data analysis and computational thinking, but are not bogged down with busy work.
   - Also unlike other units, the group project component of this unit is heavily focused on the *design* of the class model and route proposal, and the presentation of these products is secondary.
   - As students prepare their models, routes, and brief group presentations, the Project Organizers and Group Project Criteria for Success should be used as reference for the students to remind them of all components to include.

9. For presentation day, have all students help to set up their class solar system model at the start of class. We recommend use of group roles, so that the Materials Manager is in charge of actually placing the group's planet in place. This avoids the excess chaos of too many students constructing the class model at the same time.
   - Call up student groups one by one to show their telescope route and explain the points identified in their Group Project Criteria for Success checklist.
   - When presenting their proposals of the telescope routes, student groups may choose to kinesthetically model their telescope route (walking through) or they may use a physical material such as string to model their route. As a teacher, you may assign a method or leave it up to student choice.

10. Once the presentations are complete, students are ready to move on to their individual project. Students will create a presentation that pitches their route and describes the science behind it, meeting all the

criteria in the student handout. The format of the presentation is up to them (Prezi with a script, Powerpoint with a script, video, videotaped poster presentation, etc.).

11. Conduct a peer review of the presentations after students have completed a first draft.
    - Copy the Pitch Presentation Peer Review Feedback form found in the Student Instructions. Another option is to use the Student 3-Dimensional Individual Project Rubric.
    - Assign each student a partner, preferably a partner from a different group.
    - Students switch drafts and assess them using the peer review feedback form or 3-Dimensional Rubric.
        - Remind each student to give one positive comment and one constructive comment for each section on the checklist.
        - Allow students time to present their feedback to their partner, so their partner may ask clarifying questions if needed.

12. After receiving feedback, allow students time to complete a final draft based on the feedback they received.

Assessment

The Project Organizer can be formatively assessed using:
- *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix from the Unit Overview to inform your criteria.

The Group Culminating Project will be summatively assessed using:
- The *Group Project Criteria for Success* Checklist

The Individual Culminating Project will be summatively assessed using:
- The *3-Dimensional Individual Project Rubric*.
- Keep in mind that the Proficient level indicates that the student has successfully demonstrated understanding of the criteria. Because we are in the early stages of NGSS adoption, it may take multiple opportunities throughout the course of the year for students to reach Proficient.
- If you wish to give students a numeric score, you could take the average score of all of their rubrics or add up rubric scores to give students a summation out of the total. Because of the note above, this scoring may not correlate to traditional grading systems.
- While we recommend scoring all of the project criteria with the rubrics for each student, we understand the burden of that level of scoring.
    - One option is to select the rubrics that you wish to focus on for this project and use those to assess each student's individual project.
    - Another option is to review the Proficient level of each of the project's rubrics and use the descriptions to generally analyze all student work for trends.

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Overview: The following rubrics can be used to assess the individual project: a Pitch Presentation for a proposed telescope route. Each rubric is aligned to one section of the *Individual Project Criteria for Success*, located on the Culminating Project Student Instructions. *If student provides no assessable evidence (e.g., "I don't know" or leaves answer blank), then that student response cannot be evaluated using the rubric and should be scored as a zero.

Below we provide an alignment table that details the dimensions assessed for each criterion.

	Student Criteria for Success	**Disciplinary Core Idea**	**Science and Engineering Practice**	**Crosscutting Concept**
1	• Give background on the solar system, including what is in the solar system. ○ Describe the scale you used for the solar system model. ▪ As an example, explain the data you used to make your assigned planet to scale.	ESS1.B: Earth and the Solar System • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them.	N/A	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.
2	○ Draw a model that shows the layout of the solar system and how objects move in the solar system. • Explain how the solar system began and how these forces continue to hold the parts of the system together to create this layout.	ESS1.B: Earth and the Solar System • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. • The solar system appears to have formed from a disk of dust and gas, drawn together by gravity.	Developing and Using Models • Develop and use a model to describe phenomena.	Systems and System Models • Models can be used to represent systems and their interactions.
3	• Pick at least one phenomenon from each of the following lists: 1. Pick one: Seasons, lunar phases, **and/or** eclipses of the sun and moon 2. Pick one: Apparent motion of the sun, moon, **and/or** stars in the sky ○ Draw or create a model of the Sun-Earth-Moon system to show what is happening in each phenomenon. ○ Use patterns from the model to	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. 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	Developing and Using Models • Develop and use a model to describe phenomena.	Patterns • Patterns can be used to identify cause-and-effect relationships.

	explain why we experience each phenomenon on Earth.	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.		
4	• Show and describe your group's proposed route for the telescope. ○ Justify your choice in route: Use gravity to argue why the telescope needs to stay farther away from some planets, but not others. Use evidence from Task 3 to support your reasoning.	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.	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.	N/A
5	○ Cite data from Task 4 to convince non-scientific audiences that any magnetic field you create is real even though they cannot see them.	PS2.B: Types of Interactions • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	N/A	Cause and Effect • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
6	○ Describe the best ways to strengthen the magnetic field around the telescope. ▪ Identify the questions you needed to investigate in Task 4 to gather this information.	PS2.B: Types of Interactions • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	Asking Questions and Defining Problems • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	N/A

8th Grade Science Unit 2: Travelling Through Space
3-Dimensional Individual Project Rubric

7	○ Passing by planets with different magnetic fields will affect the telescope. Select one planet with a large magnetic field and draw a model to show and explain how passing by this planet would affect the telescope.	PS3.C: Relationships Between Energy and Forces • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	Developing and Using Models • Develop a model to describe unobservable mechanisms.	N/A
8	▪ On your model, label when the telescope contains the most potential magnetic energy and when it has the most kinetic energy and explain why this is the case.	PS3.A: Definitions of Energy • A system of objects may also contain stored (potential) energy, depending on their relative positions. PS3.C: Relationships Between Energy and Forces • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	N/A	Systems 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.

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Rubric 1: Student describes a background on the solar system, including an explanation of the scale for their class solar system model.

- Dimensions Assessed: DCI – ESS1.B: Earth and the Solar System, CCC – Scale, Proportion, and Quantity

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student describes an **inaccurate** background on the solar system **AND/OR** includes an **inaccurate** explanation of the scale for their class solar system model.	Student describes a **partial** background on the solar system, including an **accurate but general** explanation of the scale for their class solar system model.	Student describes a **complete** background on the solar system, including an **accurate but general** explanation of the scale for their class solar system model.	Student describes a **complete** background on the solar system, including an **accurate and specific** explanation of the scale for their class solar system model.
Look Fors: ● Student inaccurately describes what is in the solar system. For example, "The solar system consists of stars." ● And/or student does not give an accurate scale or explanation is too general. For example, "we created a smaller model."	**Look Fors:** ● Student describes a partial background on the solar system, including the sun, planets, moons, or asteroids, but not all components (which may or may not be specifically identified). ● Student accurately describes the scale of the class model: "1000 km = 1 cm for planet size and 1 AU = 10 cm for distance from the sun. The sun is not to scale." ● Student generally explains the scale for their planet but does not give specific data. For example, "We created a scale for planet size and a scale for distance between the planets to create a model that would fit in the classroom."	**Look Fors:** ● Student describes a complete background on the solar system, including the sun, planets, moons, and asteroids (which may or may not be specifically identified). ● Student accurately describes the scale of the class model: "1000 km = 1 cm for planet size and 1 AU = 10 cm for distance from the sun. The sun is not to scale." ● Student generally explains the scale for their planet but does not give specific data. For example, "We used this scale for our planet because using the same scale for both measures and the sun would make the model too large for the classroom."	**Look Fors:** ● Student describes a complete background on the solar system, including the sun, planets, moons, and asteroids (which may or may not be specifically identified). ● Student accurately describes the scale of the class model: "1000 km = 1 cm for planet size and 1 AU = 10 cm for distance from the sun. The sun is not to scale." ● Student accurately explains that they used the size and orbital radii of each planet to generate two scales and cites specific data. For example, "Mercury at 4879 km in diameter and 0.39 AU from the sun is 4.8 cm wide and 3.9 cm from the sun in the model."

8th Grade Science Unit 2: Travelling Through Space
3-Dimensional Individual Project Rubric

Rubric 2: Student draws a model to show the layout and motions of the solar system and explains the forces that hold the parts of the system together.

- Dimensions Assessed: DCI – ESS1.B: Earth and the Solar System, CCC – System and System Models, SEP – Developing and Using Models

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student draws an **inaccurate** model to show the layout and motions of the solar system **and/or inaccurately** explains the forces that hold the parts of the system together.	Student draws an **accurate** model to show the layout and motions of the solar system and **generally** explains **at least one of the** forces that hold the parts of the system together.	Student draws an **accurate** model to show the layout and motions of the solar system and **accurately** explains **one of the** forces that hold the parts of the system together.	Student draws an **accurate** model to show the layout and motions of the solar system and **accurately** explains the forces that hold the parts of the system together.
Look Fors: • Student may create an inaccurate model that shows a different planet in the middle or shows all the planets lined up in a perfect line. • Student's explanation of the forces involved in the solar system is inaccurate. For example, "The solar system has planets orbiting the sun because there are no forces in space since it is a vacuum."	**Look Fors:** • Model shows the different parts of the solar system (at least planets, but may also show moons and asteroids). Model shows objects in orbit around the sun. • Student accurately explains the role of either gravity or speed. but does so generally and without detail. For example, "The reason the solar system began and looks this way is because of gravity."	**Look Fors:** • Model shows the different parts of the solar system (at least planets, but may also show moons and asteroids). Model shows objects in orbit around the sun. • Student accurately explains the role of either gravity or speed. For example, "The solar system was first formed by dust and gas drawn together by gravity. This is the force that continues to keep planets orbiting around the sun."	**Look Fors:** • Model shows the different parts of the solar system (at least planets, but may also show moons and asteroids). Model shows objects in orbit around the sun. • Student accurately explains the roles of speed and gravity. For example, "The solar system was first formed by dust and gas drawn together by gravity. The reason this layout persists is that the sun with its large mass keeps the planets in orbit with its large gravitational pull. The speed at which the planets move allows them to orbit instead of getting pulled right into the sun."

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Rubric 3: Student draws a model of the Sun-Earth-Moon system and uses patterns from the model to explain why we experience a phenomenon on Earth.

- Dimensions Assessed: DCIs – ESS1.B: Earth and the Solar System and ESS1.A: The Universe and Its Stars, SEP – Developing and Using Models, CCC – Patterns
- **Note: Because of the breadth of ESS1.A and ESS1.B, not all examples from each DCI are assessed. Instead, students are given a choice of phenomena corresponding to each DCI. Thus, you will need to apply this rubric two times, once for each of the phenomena students choose. For more evidence of these DCIs, see student information charts from the Task 1 Explore.

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student draws an **inaccurate** model of the Sun-Earth-Moon system **and/or** uses patterns from the model to **inaccurately** explain why we experience a phenomenon on Earth.	Student draws an **accurate** model of the Sun-Earth-Moon system and uses patterns from the model to **incompletely** explain why we experience a phenomenon on Earth.	Student draws an **accurate** model of the Sun-Earth-Moon system and uses patterns from the model to **accurately but generally** explain why we experience a phenomenon on Earth.	Student draws an **accurate** model of the Sun-Earth-Moon system and uses patterns from the model to **accurately and completely** explain why we experience a phenomenon on Earth.
Look Fors: • Student model is inaccurate. For example, the Sun, Earth, and moon are shown in dramatically inaccurate relative sizes (e.g. Earth is smaller than moon) or the positions of bodies are not relevant to the phenomenon they are trying to describe. • Student describes a phenomenon inaccurately. For example, “ When the moon comes between Sun and Earth, it will be a full moon.”	**Look Fors:** • Student model shows the Sun, Earth, and moon at relative sizes and accurate positions relevant to the phenomenon they are describing. • Student explanation is incomplete. For example, “This causes seasons.”	**Look Fors:** • Student model shows the Sun, Earth, and moon at relative sizes and accurate positions relevant to the phenomenon they are describing. • Student uses the model to accurately but generally explain why we experience a phenomenon on Earth. For example, if describing eclipses, a student might show a diagram of the moon between the Earth and sun and say, “When the moon comes directly between the Earth and sun, it causes an eclipse.”	**Look Fors:** • Student model shows the Sun, Earth, and moon at relative sizes and accurate positions relevant to the phenomenon they are describing. • Student uses the model to accurately explain why we experience a phenomenon on Earth. For example, if describing apparent motion of the sun, a student might show a diagram of the Earth spinning on its axis around the sun and say, “Earth rotates on its axis each day. This makes the sun appear to move through the sky, even though it is really the Earth that is moving.”

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Rubric 4: Student argues why the telescope needs to stay farther away from some planets but not others, supporting with evidence from Task 3.

- Dimensions Assessed: DCI – PS2.B: Types of Interactions, SEP – Engaging in Argument From Evidence

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **inaccurately** argues why the telescope needs to stay farther away from some planets but not others.	Student **accurately** argues why the telescope needs to stay farther away from some planets but not others, supporting with **no** evidence from Task 3.	Student **accurately** argues why the telescope needs to stay farther away from some planets but not others, supporting with **one piece** of evidence from Task 3.	Student **accurately** argues why the telescope needs to stay farther away from some planets but not others, supporting with **multiple sources** of evidence from Task 3.
Look Fors: • Student explanation is accurate. For example, "Some planets have a stronger magnetic field, which creates a higher gravitational pull, so the telescope needs to stay away from those."	**Look Fors:** • Student explanation is accurate. For example, " Some planets have larger masses and more mass means more gravitational attraction. Thus, the telescope should stay farther away from planets with greater mass to avoid getting pulled into their gravitational field." • However, student cites no evidence to support this argument.	**Look Fors:** • Student explanation is accurate. For example, " Some planets have larger masses and more mass means more gravitational attraction. Thus, the telescope should stay farther away from planets with greater mass, such as Jupiter and Saturn, to avoid getting pulled into their gravitational field." • Student supports the argument with only one piece of evidence from Task 3. For example, "The pHet simulation showed us that increasing the mass of the Sun or Earth increased gravitational attraction and caused collisions."	**Look Fors:** • Student explanation is accurate. For example, " Some planets have larger masses and more mass means more gravitational attraction. Thus, the telescope should stay farther away from planets with greater mass, such as Jupiter and Saturn, to avoid getting pulled into their gravitational field." • Student supports the argument with multiple sources of evidence from Task 3. For example, "The pHet simulation showed us that increasing the mass of the Sun or Earth increased gravitational attraction and caused collisions. Similarly, the data table from task 3 showed us that as planet mass increases, the rate of falling rock increases, which means gravity increases."

8th Grade Science Unit 2: Travelling Through Space
3-Dimensional Individual Project Rubric

Rubric 5: Student predicts that any magnetic field they create will be present even though we cannot see them, citing data to back up this claim.

- Dimensions Assessed: DCI – PS2.B: Types of Interactions, CCC – Cause and Effect

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student predicts that any magnetic fields they create will be present even though we cannot see them, but uses **no** data to back up this claim.	Student predicts that any magnetic field they create will be present even though we cannot see them, using **general trends in** data to back up this claim.	Student predicts that any magnetic field they create will be present even though we cannot see them, using **general trends and one specific source of** data to back up this claim.	Student predicts that any magnetic field they create will be present even though we cannot see them, using **accurate and specific** data **from multiple sources** to back up this claim.
Look Fors: • Student makes the claim from the criteria, but does not use any data to back it up. For example, "Even though we can't see magnetic fields, there is lots of evidence that they are real."	**Look Fors:** • Student uses general trends from multiple sources to back up their claim, but no specific data. For example, "Even though we can't see magnetic fields, there is lots of evidence that they are real. We did many experiments that support this claim. In all the experiments, there appeared to be some invisible force either keeping objects apart or pulling them together, even when not touching."	**Look Fors:** • Student uses general trends from multiple sources to back up their claim, but only specifically cites one source. For example, "Even though we can't see magnetic fields, there is lots of evidence that they are real. We did many experiments that support this claim. In all the experiments, there appeared to be some invisible force either keeping objects apart or pulling them together, even when not touching. In Experiment 1, for example, when we put two magnets with the same poles oriented towards each other, there was an invisible force that kept them apart."	**Look Fors:** • Student uses multiple sources to back up their claim, citing specific observations. For example, "Even though we can't see magnetic fields, there is lots of evidence that they are real. We did many experiments that support this claim. In Experiment 1, when we put two magnets with the same poles oriented towards each other, there was an invisible force that kept them apart. In Experiment 2, we could move a paper clip with a magnet without them actually touching. Similarly, In Experiment 3, we could pick up paperclips with a wire-wrapped nail connected to a battery without them touching at first."

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Rubric 6: Student describes the best ways to strengthen the magnetic field around the telescope and identifies relevant questions that were investigated to gather this information.

- Dimensions Assessed: DCI – PS2.B: Types of Interactions, SEP – Asking Questions

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **inaccurately** describes way**(s)** to strengthen the magnetic field around the telescope and does not identify relevant questions that were investigated to gather this information.	Student **accurate**ly describes way**(s)** to strengthen the magnetic field around the telescope **but does not** identify relevant questions that were investigated to gather this information.	Student **accurate**ly describes **a** way to strengthen the magnetic field around the telescope and identifies **a** relevant question that was investigated to gather this information.	Student **accurate**ly describes **multiple** ways to strengthen the magnetic field around the telescope and identifies relevant question**s** that were investigated to gather this information.
Look Fors: • Student inaccurately identifies factors that strengthen magnetic fields. For example, "changing the direction of the pole." • Thus, any questions identified are irrelevant.	**Look Fors:** • Student accurately identifies factors (one or multiple) that strengthen magnetic fields. For examples, see right-hand column. • Student does not identify the questions they investigated relevant to the factors they identified. For example, they may say "What is a magnetic field?"	**Look Fors:** • Student accurately describes one factor that strengthens magnetic fields. For examples, see right-hand column. • Student identifies a question they investigated relevant to the factor they identified. For example, if a student identifies increasing the battery voltage as the factor to strengthen the magnetic field, the question could be: "How did battery size affect the strength of the magnetic fields?"	**Look Fors:** • Student accurately describes multiple factors that strengthen magnetic fields. For example: creating more loops in the coil, changing the core metal to metals like iron or neodymium, increasing the battery voltage, changing the metal of the wire, etc. • Student identifies the questions they investigated relevant to the factors they identified. For example, if a student identifies creating more loops in the coil and changing the core metal as the factors to strengthen the magnetic field, the questions could be: "What magnet materials seemed to be more attractive? How did the number of coils affect the magnetic field? How do we know when the magnetic field is strong?"

8th Grade Science Unit 2: Travelling Through Space

3-Dimensional Individual Project Rubric

Rubric 7: Student draws a model to show and explain how passing by planets with different magnetic fields will affect the telescope.

- Dimensions Assessed: DCI – PS3.C: Relationships Between Energy and Forces, SEP – Developing and Using Models

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student draws an **inaccurate** model to show and explain how passing by planets with different magnetic fields will affect the telescope.	Student draws an **accurate** model to **generally** show how passing by planets with different magnetic fields will affect the telescope. OR Student **accurately explains** how passing by planets with different magnetic fields will affect the telescope.	Student draws an **accurate** model to **generally** show **and explain** how passing by planets with different magnetic fields will affect the telescope.	Student draws an **accurate** model to **accurately** show and explain how passing by planets with different magnetic fields will affect the telescope.
Look Fors: ● Student model and explanation are inaccurate. For example, a student may show the telescope accelerating toward Jupiter.	**Look Fors:** ● Student draws a model of the telescope's interaction with a planet that has a large magnetic field (Ex: Jupiter and Neptune). Model shows the general interaction but does not use specific written explanation to describe the effect and why it is happening. OR ● Accurate explanation is present but model is missing. See Advanced Look-Fors for an accurate student response.	**Look Fors:** ● Student draws a model of the telescope's interaction with a planet that has a large magnetic field (Ex: Jupiter and Neptune). ● Model generally shows and explains how passing by a planet with a large magnetic field will cause the telescope to spin and align, but the specifics of this alignment are not explained in detail, as shown in the Advanced Look Fors.	**Look Fors:** ● Student draws a model of the telescope's interaction with a planet that has a large magnetic field (Ex: Jupiter and Neptune). ● Model accurately shows and explains how passing by a planet with a large magnetic field will affect the telescope. For example, "Passing by a planet with a large magnetic field will cause the telescope to spin so that one pole of the telescope's field aligns with the opposite pole of the planet's field. This will not happen if there is not a strong magnetic field." As a comparison, this is similar to how the north side of a bar magnet would be attracted to the North Pole (which is actually a south magnet).

8th Grade Science Unit 2: Travelling Through Space
3-Dimensional Individual Project Rubric

Rubric 8: Student labels a telescope model to show moments of most potential magnetic energy and most kinetic energy and explains the interaction of these forms of energy within the magnetic system.

- Dimensions Assessed: DCI – PS3.A: Definitions of Energy and PS3.C: Relationships Between Energy and Forces, CCC – Systems and System Models

Emerging (1)	Developing (2)	Proficient (3)	Advanced (4)
Student **inaccurately** labels a telescope model to show moments of most potential magnetic energy and most kinetic energy.	Student **accurately** labels a telescope model to show moments of most potential magnetic energy and most kinetic energy **but does not** explain the interaction of these forms of energy within the magnetic system.	Student **accurately** labels a telescope model to show moments of most potential magnetic energy and most kinetic energy and **generally** explains the interaction of these forms of energy within the magnetic system.	Student **accurately** labels a telescope model to show moments of most potential magnetic energy and most kinetic energy and **specifically** explains the interaction of these forms of energy within the magnetic system.
Look Fors: • On their model, student does not accurately label "potential magnetic energy" and "kinetic energy" (See Look Fors in other columns for correct locations).	**Look Fors:** • On their model, student accurately labels "potential magnetic energy" at a point when the telescope is beginning to spin and "kinetic energy" at a point towards the end of the telescope's spin. • Student does not offer a specific explanation for their labels or explanation is inaccurate or irrelevant to their labels.	**Look Fors:** • On their model, student accurately labels "potential magnetic energy" at a point when the telescope is beginning to spin and "kinetic energy" at a point towards the end of the telescope's spin. • Student explains this relationship accurately, but without complete detail. For example, "As the telescope spins, the potential energy is transformed into the kinetic energy."	**Look Fors:** • On their model, student accurately labels "potential magnetic energy" at a point when the telescope is beginning to spin and "kinetic energy" at a point towards the end of the telescope's spin. • Student explains this relationship specifically. For example, "Changing the orientation of the telescope's magnet in relation to the poles in the corresponding planet affects the amount of potential energy. As the telescope begins to spin, potential energy is transformed into the kinetic energy."

8th Grade Science Unit 2: Travelling Through Space
Project Organizer

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

You will be developing a model of the solar system and proposing the best route a new telescope should take through space. After each task, you will return to the table below to organize what you learn as you go through the unit. By the end of the four tasks, you will have all this information to use for your culminating project. For each activity, be sure to include answers to **ALL** the questions provided.

Lift-Off Task: Our Solar System	You will be launching a new telescope into our solar system, so we need to know what is out there. What do you think our solar system consists of?
Task 1: A Sun-Earth-Moon Model	In order to plan a route through the solar system for the new telescope, you will need to know what it looks like. The best way to imagine what it looks like is to create a model. To prepare you to construct a full solar system model, you have practiced this skill by creating a Sun-Earth-Moon system model. In the process, you have discovered the science behind many things you experience on Earth! ❑ Draw a sketch of your Sun-Earth-Moon model with labels. ❑ Use your model to describe at least two of the phenomena explored in this task. ❑ What are the limitations of the model you have drawn? In other words, how does it not accurately represent the Sun-Earth-Moon system?

8th Grade Science Unit 2: Travelling Through Space
Project Organizer

Task 2: A Solar System Model	To plan a route for the new telescope, you will need to know more than just the Sun-Earth-Moon System and more than just a list of total parts; you will need a specific layout. Draw a sketch of your class solar system model, including where the new telescope needs to arrive. ❑ In captions, explain the scale you used for your assigned planet within the model. o What data did you use? o How does it compare to other planets in the solar system model?

8th Grade Science Unit 2: Travelling Through Space
Project Organizer

Task 3: Gravity in the Galaxies	Even though you already have the layout of the solar system, you now know that these objects don't just remain stationary…they move because of gravity! Based on what you've learned about mass, gravity, and motion, draw a potential route for the new telescope on the sketch you made in the Task 2 section above. Then in this section: ❒ Explain why the solar system is laid out the way it is: what is the role of gravity in the solar system? ❒ Use your model and data from the task to explain how gravity might affect the new telescope as it moves through space. ❒ Justify your route by explaining why you stay farther away from some planets, but not others.

8th Grade Science Unit 2: Travelling Through Space

Project Organizer

Task 4: Invisible Forces	We need to protect the new telescope from solar wind as it travels through space. Scientists say that the new and best protection is to create a magnetic field around the telescope. But how do we do this? Use what you have learned to make some recommendations for a protective magnetic field. ❒ How will we know a magnetic field has been created? We can't see them, so what evidence is there that magnetic fields exist? ❒ What kinds of factors affect the strength of magnetic fields? ▪ What questions did you have to investigate to find out this information? ❒ Research magnetic fields on different planets. Based on what you learned about the arrangement of objects and potential energy, how might the telescope be affected as it passes these different planets?

8th Grade Science Unit 2: Travelling Through Space
Lift-Off Task: Our Solar System

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction

Until 400 years ago, all that we knew about our solar system came from observations with the naked eye. This made it really difficult to know what was in our solar system, how these objects were arranged, and how they moved throughout the system. Then, telescopes were invented and we could suddenly see planets and stars in more detail than we ever thought possible. In the last few decades, scientists took this a step further and developed a telescope that could actually be launched into space. The first was known as the Hubble Space Telescope and has been orbiting Earth for more than 25 years with an unobstructed view of the universe. For this unit's project, students will be operating under the context that NASA has developed a more advanced space telescope that will go even farther out into our solar system; they need to learn everything they can about the solar system to help the new telescope reach its destination. This Lift-Off Task asks students to draw off their own prior knowledge to generate questions around the phenomenon of our solar system—questions that they will continue to explore throughout this unit.

Alignment Table

Because the Lift-Off tasks focus on student-generated questions, we do not identify specific Disciplinary Core Ideas or Science and Engineering Practices in this table.

Crosscutting Concepts (*depending upon student-generated questions)

- Patterns
  - Patterns can be used to identify cause-and-effect relationships.
- Cause and Effect
  - Cause and effect relationships may be used to predict phenomena in natural or designed systems.
- 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.
- Systems and System Models
  - Models can be used to represent systems and their interactions.
  - Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy and matter flows within systems.

Equity and Groupwork

- Share and listen to broad and diverse student contributions.
- Make connections between each other's ideas.
- Work together to co-construct a concept map.

Language

- Use connector words to link ideas.
- Generate and write questions about the phenomenon.
- Organize key questions in a concept map.

8th Grade Science Unit 2: Travelling Through Space
Lift-Off Task: Our Solar System

Learning Goals

This learning task introduces students to the phenomenon of our solar system and asks them to begin generating questions that will guide them through the unit. More specifically, the purpose is to:

- Individually generate a list of questions about our solar system.
- Make connections between related questions.
- Generate possible answers to questions, using prior knowledge.
- Apply prior knowledge of our solar system to make a list of solar system parts that a telescope would have to navigate through in order to be launched into space.

Content Background for Teachers

Students have likely studied the solar system in prior grades and know that a solar system consists of a star and all the objects that travel around it – planets, moons, asteroids, comets, and meteoroids. In the case of our solar system, the central star is the sun and is much larger than all the other bodies that travel around it. There are likely tens of billions other solar systems in the Milky Way Galaxy alone, but for the sake of this unit, we will be focused on our own solar system.

At this point in the unit, we are building off of students' prior knowledge of our solar system, asking students to generate questions they would need to ask to make sense of this phenomenon. These might be questions related to what they would find in the solar system, the arrangement of these objects, the movement of these objects, how this system came to be, and much more.

Our solar system consists of eight planets and their moons, as well as dwarf planets and their moons. The eight planets in order from the sun are: Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune (Pluto is no longer considered a planet by most scientists). All of these planets orbit the sun and have a different orbital radii and speed that results in the particular arrangement of our solar system.

How did this configuration come to be? About 4.5 billion years ago, a dense cloud of interstellar gas and dust collapsed, forming a solar nebula, or a swirling disk of material. At the center, gravity pulled more and more material in until the pressure was so great that hydrogen atoms began to combine into helium, releasing tons of energy. The sun was born from this interaction, using up 99% of the matter. However, matter farther out was also clumping together, forming larger objects. Some became planets, dwarf planets, and large moons. Others never quite came together and are part of the asteroid belt. As one can see, gravity is essential, not only in the making but also in the maintaining of our solar system as we know it today. Students will explore these and other concepts in more depth as they go through the unit.

In this task, students create a concept map, which is a graphical tool that helps to organize and represent knowledge and questions, and is a successful academic language instruction tool. As students learn more about the solar system, they will add more questions and ideas to this concept map. If your students have not had previous experience making concept maps, please see the instructions in Part B below for strategies on teaching this skill.

8th Grade Science Unit 2: Travelling Through Space
Lift-Off Task: Our Solar System

Academic Vocabulary
- Solar System
- Telescope
- Space

*Additional academic vocabulary will vary by class

Time Needed (Based on 45-Minute Periods)
2 Days
- Introduction, Part A and Part B: 1 period
- Class Concept Map, Project Overview, and Project Organizer: 1 period

Materials
- Unit 2, Lift-Off Task Student Version

Part A
- Computer and Projector (for images)

Part B
- Poster paper and markers
- Post-Its (Optional)

Part C
- Class Poster Paper and markers
- *See Instructions below for other optional materials to use for the class concept map

Connecting to the Culminating Project
- Culminating Project Handout
- Project Organizer Handout

Instructions

1. Introduce students to the unit by reading or projecting the Unit Essential Question aloud.

2. Read the short paragraph on page 1 of the student guide aloud, which introduces the phenomenon for the unit: our solar system. Then show a variety of images taken from the Hubble Space telescope to spark any prior knowledge students have about our solar system: https://www.spacetelescope.org/images/archive/category/solarsystem/. Do not show students any captions from the images as we want students to generate their own questions from their own prior knowledge.

Part A
1. In this Lift-Off task, students will be generating questions to help them make sense of the phenomenon.

2. Have students complete this section individually in their student guide.

- For students who need more support, encourage them to think of the telescope images they observed, visualize a picture of our solar system in their heads, and consider any questions they have.
- Here is a list of some potential questions students might generate: "What is in our solar system? Where does our solar system end? How did the solar system form? How do objects move in the solar system? Why can't I see all the objects in the solar system from Earth? Why is it called a solar system?"

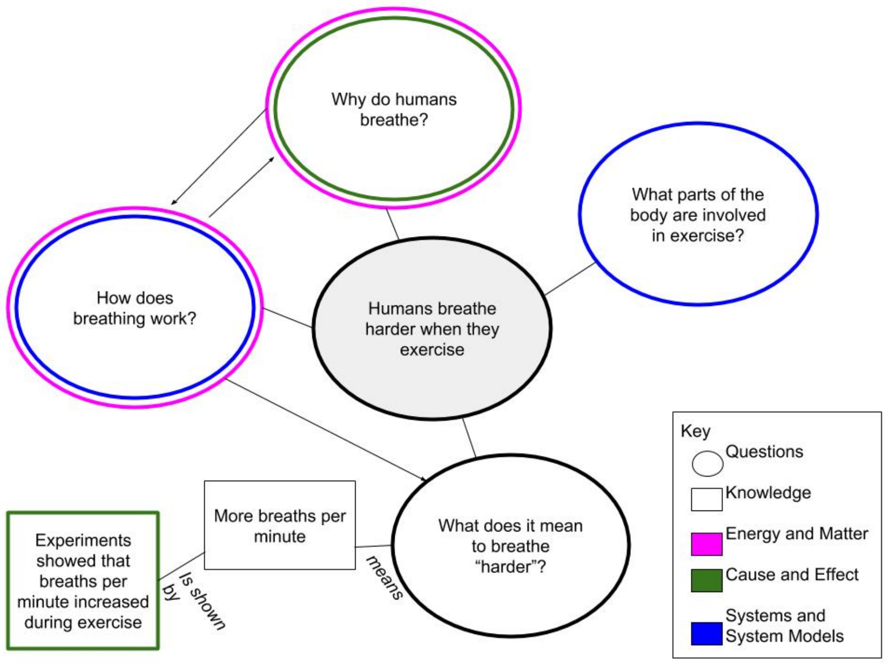
Part B:

1. In this part of the task, students create a concept map as a group.
    - Remind students to refer to the directions on their student guide to help them make their concept map. First, students should compare each member's list of questions and record/connect key questions on a piece of poster paper. They will then draft possible answers to the questions, using prior knowledge.
    - Remind students that there are no right or wrong questions or predictions, so students feel encouraged to contribute any and all questions and ideas they think of.
    - Because this is a collaborative task, it is recommended that you remind students of group work norms and assign group roles, such as Resource Manager, Facilitator, Recorder, and Harmonizer (See "How to Use this Curriculum" for more details).

2. Students will post their posters on a wall and then walk around and look at each group's ideas. One suggestion for gallery walks is for students to interact with the posters in some way. For example, students are required to initial or leave post-its on three questions that they are also excited about on other posters.

How to Concept Map

For students who have not had a lot of experience making concept maps, we have detailed a strategy below for introducing concept mapping using more familiar content. An example is also provided, but this will vary depending on what your students come up with as you make your own model.



1. Write the phenomenon in the middle of the poster, in this case "Humans breathe harder when they exercise."

2. Ask students to share questions they might ask to make sense of this phenomenon and make a list of these questions on the board.

3. Model the process of reviewing the list and finding similarities amongst the questions.
   - Place these key questions on the concept map poster, modeling how to put similar questions near each other on the poster. Circle these to signify that these are questions, not content knowledge.

4. Ask students to look at the key questions and see if any of the questions are connected: Would answering one question lead to one of the other questions? Model making these connections by drawing arrows between the circles.

5. In this Lift-Off task, students will only be drafting possible answers to the questions, not actually gathering and recording learned concepts. However, throughout the unit, they will be adding content they have learned. Model this by recording a student's prior knowledge to one of the questions, using boxes to signify that these are pieces of content knowledge rather than questions.
   - Use connector words to identify the relationships between the content boxes (See image above for an example).

6. Optional: To emphasize crosscutting concepts using a concept map, make a key of different colors for the crosscutting concepts emphasized in this unit. Identify questions that clearly show evidence of the different crosscutting concepts and circle them with the corresponding colors. Explain to students how you made that choice by pointing out the language that hints at that crosscutting concept. *Note: not all boxes and circles will necessarily have a crosscutting concept.

8th Grade Science Unit 2: Travelling Through Space
Lift-Off Task: Our Solar System

Part C

1. Construct a whole-class concept map that begins to help students make sense of the phenomenon of our solar system.
    - Start with the phenomenon in the middle.
    - Then ask students to share out the questions that were most common across all the posters in the classroom. As you record questions on the poster, organize them based on connections you see. Draw circles around each question (as you add to the concept map throughout the unit, you'll also be adding concepts learned, which can be written in boxes to distinguish them from the questions).
    - Ask students to identify any connections they see between the questions and record these as lines between the questions.
        - Recommended: Give pairs of students think time to come up with 1-2 connections to add to the class concept map and call on pairs using equity sticks. This encourages more equitable participation in this class-wide activity.
    - The purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.
    - This whole class concept map will be revisited at the end of each subunit, asking students questions like: Are there any new questions you have about the phenomenon? Are there any connections you want to add or change? What is your reason for that addition/revision? Are there more connections we can make between the questions/ideas already on the map? Do you want to add any new ideas/concepts to the map?

2. Because this concept map will be added to and revised throughout the unit, here are some practical options for implementation.
    - If you have access to white board paper, we encourage you to use these for class posters since it will allow you and your students to make revisions throughout the unit.
    - Another option is to use smaller pieces of paper for each class and project using a document camera; this will save space as opposed to doing large class posters.
    - We highly recommend students keep their own version of this concept map in their notebooks, adding questions and concepts as they go through the unit.

3. Once the draft concept map is complete, introduce students to the crosscutting concepts for this unit. We recommend posting posters of each crosscutting concept in your classroom (See beginning of teacher guide for templates).
    - The crosscutting concepts for this unit are: Patterns; Cause and Effect; Scale, Proportion, and Quantity; and Systems and System Models. Assign a color for each crosscutting concept that can be used throughout the unit.
    - Have students analyze the class concept map for as many examples of the crosscutting concepts as they can find. Depending on the questions they have, they may be able to find an example of each of the crosscutting concepts or perhaps just some.

    - We recommend modeling this process by picking a question, identifying the crosscutting concept, and tracing the circle in the corresponding color. Explain the key words that helped you identify the crosscutting concept in this question. Some identifying words that students might look for are:
        - **Patterns**: These could be phrases such as, “is the same as”, “has in common with”, “is similar to”, “shares” etc.
        - **Cause and Effect:** These could be phrases such as, “that results in,” “that causes,” “that explains why,” “is due to,” etc.
        - **Systems and Systems Models**: These could be phrases such as, “is a part of” “connects to,” “interacts with,” “is made up of,” “works together with,” etc.
        - **Scale, Proportion, and Quantity**: These could be phrases such as, “is proportional to,” “compared to,” “has a ratio of,” “is bigger/smaller than,” “is longer/shorter than,” etc.

Connecting to the Culminating Project

1. Hand out the Culminating Project Task Card and read the Challenge and Group Project Criteria for Success aloud as a class.
    - Take questions for clarification.

2. Give a brief overview of the Background on the new telescope. This will give students detail on where the new telescope will need to be launched.

3. Pass out their Project Organizer and explain that they will complete a section of this after each task in class. Students should independently complete the Lift-Off Task section of the Project Organizer in class. Revisions can be done for homework, depending upon student’s needs and/or class scheduling.
    - Students have been tasked with developing a model of the solar system and proposing the best route a new telescope should take through space. The student prompt is as follows: You will be launching the new telescope into our solar system, so we need to know what is out there. What do you think our solar system consists of?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you made a list of all the questions you have about the solar system. Look back at your list: think about the questions your peers asked that you did not initially write down. How are their questions different from the ones you originally asked?
    - In this unit, we will be focusing on four crosscutting concepts: **Patterns**: patterns can be used to identify cause and effect relationships; **Cause and Effect**: cause and effect relationships may be used to predict events; **Scale, Proportion, and Quantity**: scaled models can be used to study time, space, or energy systems that are too large or too small; **Systems and System Models**: models can be used to represent systems and their interactions. Looking at your class concept map, give one example of how a crosscutting concept came up in today’s task.
    - Now that you understand what project you’ll be working on over the course of this unit, what else do you need to know? What additional questions do you have?

2. There are no right answers, but encourage students to look back at their initial lists and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their questions and ideas based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and the gathering of knowledge and skills for their final project.

8th Grade Science Unit 2: Travelling Through Space
Task 1: A Sun-Earth-Moon Model

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction

In the Lift-Off Task, students were introduced to the motivation behind this unit—charting a route for a new telescope through our solar system. Using their prior knowledge, they created lists of all the different things they think they might find in a solar system. However, in order to chart a route through the solar system, it is not enough to just know what is there—they must find out where things are and how they are laid out within the system. The best way to visualize such a large system is to create a model. In this task, students will practice modeling with the smaller sub-system of the Sun-Earth-Moon system. In doing so, they will discover explanations for a lot of the phenomena they experience on Earth, giving them a more complex picture of the solar system for their culminating project.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.]	**Developing and Using Models** • Develop and use a model to describe phenomena.	**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. **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	**Patterns** • Patterns can be used to identify cause-and-effect relationships.

8th Grade Science Unit 2: Travelling Through Space
Task 1: A Sun-Earth-Moon Model

		of sunlight on different areas of Earth across the year.	

Equity and Groupwork • Use group roles to engage with models of various phenomena. • Work together to create a mini-video.
Language • Connect visual representations to verbal and written explanations. • Write an explanation with reasoning and evidence.

Learning Goals

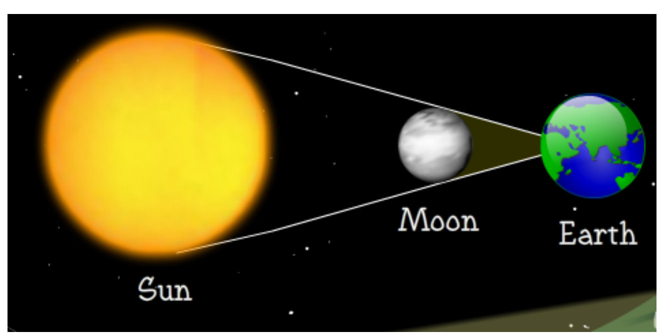
This learning task asks students to use and develop models to explain celestial phenomena. More specifically, the purpose is to:

- Engage prior knowledge of everyday experiences involving the Sun, Earth, Moon, and stars.
- Develop and use models to investigate these phenomena.
- Create a video model to explain how one phenomenon works.
- Use knowledge to explain a difference in seasons in different global locations.
- Apply knowledge of the Sun-Earth-Moon system to explain a sub-system of the solar system and identify limitations in a model.

Content Background for Teachers

This task dives into a specific subsystem in order to explain certain phenomena we experience on Earth and give students practice at modeling. In this task, students engage with five phenomena related to the Sun-Earth-Moon system: apparent motion of the sun in the sky, seasons, lunar phases, visibility of stars during different seasons, and eclipses. Students will find that all of these involve two main motions affecting Earth: its rotation around its axis and its rotation around the sun.

In Resource Card 1, students consider why the sun appears to move in an arc across the sky every day. This is not because the sun is actually moving, but because the Earth is rotating on its axis each day. This leads into Resource Card 2, in which students learn that the Earth is in orbit around the sun, but is always tilted slightly in the same direction. This means that at different times of year, sunlight will be angled more directly on certain parts of the Earth. These changes in sunlight intensity as the Earth orbits the sun throughout a year are what cause seasons. This becomes the basis of the scenario in the Elaborate.



Resource Cards 3 and 5 add the moon into the mix, which orbits the Earth. When the moon comes directly between the Earth and sun, it can cause an eclipse, or a blocking of the sun's light, casting a shadow of darkness on some areas of the Earth. Resource Card 3 asks students to think about a more common phenomenon - lunar phases. Ultimately, the light of a full moon we see is because the moon is on the other side of the Earth and the sun is shining on it. When the moon is in between the sun and the Earth (but not covering the sun), the side of the moon facing us receives no direct sunlight—we see this as a new moon.

Lastly, students consider how the stars appear to change at different points in the year. On any given evening, you are only able to see the stars that are in the opposite direction to the sun because this is the direction you face at night. All the stars that are "behind" the sun are only viewable during the day; however, because of we can only see stars at night, we never actually see these. Because the Earth orbits the sun, the visible stars will change throughout the year. In this investigation, students might also notice that stars, just like the sun, appear to move across the sky at night. This is again due to the rotation of Earth in a day.

In gaining all this content knowledge through the use of models, students will better be able to understand the interacting pieces of a system and will be able to use these modeling skills in the next task. For more information on any of these concepts, please see the resource cards associated with this task.

Academic Vocabulary

- Season
- Eclipse
- Lunar Phase
- Sun
- Earth
- Moon
- Axis
- Rotation
- Orbit
- Angle

Time Needed (Based on 45-Minute Periods)

6 Days

- Engage: 0.5 period
- Explore: 2 periods
- Explain: 2 periods
- Elaborate: 0.5 period
- Evaluate and Reflection: 1 period

Materials

- Unit 2, Task 1 Student Version

Explore

- Station Cards 1 - 5: two - three per station
- Stations 1, 2, and 5: Computers/Tablets (Make sure interactives/videos work)
- Station 3: Styrofoam ball with embedded toothpick and light source (ex: lamp)

Explain (Per Group)

- Styrofoam Balls of varying size
- Skewers/Toothpicks

- Light sources of varying brightness
- Rubber band
- Marker
- Device with video capabilities

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 1: In the Lift-Off task, we used space telescope images to help us make lists of what we think is in our solar system. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 1: However, to prepare to launch a telescope through space, we don't just need to know what is in our solar system, but where they are in our solar system. The best way to visualize something so huge is by creating **models**. Before creating a model of our whole solar system, you are going to practice with a very important sub-system—the Sun-Earth-Moon system. Understanding how this system works helps to explain a lot of the phenomena you experience on Earth!
    - Now pass out their Task 1 student guide.
    - This transition paragraph, which is also present on their student guide, introduces students to the science and engineering practice that they will focus on throughout the unit—**Developing and Using Models**. More specific information about how students develop and use models is provided throughout this task.

3. In pairs, have students make predictions about the science behind some phenomena they experience on Earth. These phenomena will be weaved throughout the entirety of the task. This activity allows students to begin engaging with the crosscutting concept of **Patterns**, as students use their own prior knowledge of various patterns to predict cause-and-effect relationships. They will come back to these relationships as they collect evidence over the course of the task.
    - We recommend doing this activity in pairs so students have the space to voice all their own ideas, but also have a partner to brainstorm with if they are having trouble thinking of ideas.
    - Share out ideas in a class-wide discussion, emphasizing to students that "correct" answers are not important at this point. The use of equity sticks is encouraged for more equitable participation in class-wide discussions like these (See "How To Use This Curriculum" for more details).

Explore

1. Now that students have made predictions, they need to gather more information on the science behind these phenomena.

- All of the stations will give students practice at **Using Models** to investigate different phenomena they experience on Earth. As they use the models, students are gathering evidence of different **Patterns** that they can use to explain how the Sun, Earth, and Moon interact to cause these phenomena.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   - Ask the Facilitator to read the directions, make sure everyone understands the task, and facilitate discussion.
   - Ask the Materials Manager to handle any resources needed to complete the task, including computer resources.
   - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
   - Ask the Recorder to make sure the group is recording their observations and conclusions in their student guides.

3. Set up 5 stations around the room (you may want to have duplicate stations depending on the number of student groups you have). At each station, lay out 2-3 copies of one station card and any other resources necessary (see materials list above).
   - Students will circulate between the stations to gather information. It is recommended that you set a specific time for each station (ex: approximately 7 minutes) so students really spend time doing deep analysis of the data.
   - Walk around and listen to the kind of evidence students are discussing.
     - Try not to provide any explicit analysis, but you may point out parts of the information or simulation to focus on if students are struggling. Students may need explicit help with navigating the simulations.
     - The discussion questions provided on the station cards are meant to provide facilitation and scaffolding for collection of information.
   - Students should fill out the information collection table in their student guide in order to record and organize their findings.
   - *Note: For Station 3 (Shapes of the Moon): if you are short on materials or ability to create a dark space, you can have students watch a video of a teacher acting out the model. The link is in the "Sources" section on that resource card.

Sample Student Information Collection Chart

	Observations: What does this model tell you about the Sun-Earth-Moon system?	**Discussion Questions**
Resource Card 1: Sun's Movement Through the Sky	*This tells us that the sun does not actually move, but rather the Earth rotates on its axis once in a day, which makes the sun look like it is moving.*	1. What did people previously believe about the movements of Sun and Earth? *They previously believed that the sun orbited the Earth.* 2. Is the sun actually moving or are you moving? *The sun is not moving; we are moving because the Earth is*

		moving. 3. How can you explain why the sun appears to be moving through the sky during a day? *The Earth is rotating on its axis, so your orientation to the sun is changing throughout the day.* 4. How is the model at the end of this video limited (inaccurate in some ways)? *It is limited because it is not drawn to scale and the Earth is not tilted on its axis.*
Resource Card 1: Seasons	*This tells us that the Earth orbits the sun at a tilt, which causes different intensities of sunlight on different areas throughout the world. This creates seasons.*	1. Does the Earth stay in one place throughout the year? If not, describe its motion and location in the solar system? *It moves throughout the year, in an orbit around the sun.* 2. Why does the angle of the sun at noon seem to change at different months throughout the year? *The Earth is tilted so the angle of the sun in an area depends on which hemisphere is angled toward the sun. Because Earth orbits around the Earth, this changes for an area throughout the year.* a. How does this create seasons? (Hint: Read the drop-down box entitled "About Seasons" if you are stuck). *The axis is tilted, so parts of the Earth that receive more direct sunlight changes throughout the year. This causes seasons.* 3. What do you notice about the angle of Earth? *It is tilted on its axis.* 4. How do you think this affects the seasons in different hemispheres (halves) of the world? *This means that when light is shining more directly on one half, it is shining less directly on the other half. That is why Melbourne and New York have different seasons at the same time.*
Resource Card 3: Shapes of the Moon	*It tells me that the different lunar phases we see are because of where the moon is in its orbit, in relation to the sun. We only see the moon when the light from the sun shines on it. If it is between the Earth and sun and doesn't receive direct sunlight, you don't see a moon.*	1. No matter where the moon is in its orbit around the Earth, how much is lit up? *Half of it.* a. Where does the light source come from? *The sun.* 2. When the moon is between the Earth and the sun, what do you observe from Earth's perspective? *You can't see any of the moon.* a. What type of moon do you think this is (Full Moon, Crescent Moon, Quarter Moon, New

		Moon)? *New Moon.* 3. When the Earth is between the moon and the sun, what do you observe from Earth's perspective? *You can see the whole moon.* a. What type of moon do you think this is (Full Moon, Crescent Moon, Quarter Moon, New Moon)? *Full Moon* 4. Does the shape of the moon actually change? If not, what is actually happening? *The shape of the moon does not change. It is always a sphere, but we only see the part that is lit up.*
Resource Card 4: Changing Stars in the Sky	*This resource shows me that Earth's orbit around the sun has yet another effect. It allows us to only see certain stars at certain times of year.*	1. Take a look at the image above. On a summer night, what stars are visible? Why do you think those are the ones that are visible? *Sagittarius, Lyra, and Hercules. These are the only ones visible because they are in the direction you are facing at night during that time of year.* 2. Why wouldn't you be able to see Orion and Canis Major on a summer night? (Hint: at what time of day do you view stars?) *You can't see those stars because you would face them during the day time and you can't see stars during the day time.* 3. Can this phenomenon be explained by the rotation of Earth on its axis OR the rotation of the Earth around the sun? Explain how. *This is explained by the rotation of Earth around the sun; that is why the stars you see changes throughout the year. The fact that the stars appear to move throughout the night is due to the rotation of Earth on its axis.*
Resource Card 5: Eclipses	*This tells us that one way they interact is when the moon orbits around the Earth, it can occasionally block the sun. This is called an eclipse.*	1. This picture is not drawn to scale, but helps you to compare the relative sizes of the Earth, sun, and moon. What is the biggest object in this picture? *The sun.* 2. A solar eclipse happens when the sun is completely blocked by the moon. How could that be possible if the sun is so much larger? *The moon is much closer to Earth than the sun, causing it to look the same size from Earth.* 3. How often does this phenomenon occur? *About once every 18 months.*

		4. How do the motions of the Earth, sun, and moon make this possible? *The Earth orbits the moon, and the moon orbits the sun, causing the moon to occasionally be in the path between the Earth and sun.*

Explain

1. Students then use all the information they have gathered to make a mini-video explaining one phenomenon using a physical Sun-Earth-System model they create.
    - Here students are moving away from merely using models to **Developing Models** in order to describe one specific phenomenon. Students will use the patterns they observed in the stations to explain why we experience a phenomenon on Earth. This reinforces the crosscutting concept of **Patterns** as students use patterns to identify a cause-and-effect relationship.

2. First, have students build their models in groups, using the materials listed on their student guides.

3. Then have groups make a mini-video, using their model to explain how one of the phenomena works (except for lunar phases since they made a model as part of the station).
    - We highly recommend students develop a plan on their student guides before moving on to record a video. If desired, you may require students to submit these plans as a checkpoint before moving on to video recording.

4. Once complete, these videos provide an excellent resource to be used throughout the unit.
    - Optional: Select the most accurate and engaging video for each phenomenon (for lunar phases, you can use the video link on the resource card). Present each of the videos as a review before moving on to the next task or at the end of the unit before they begin working on their group culminating project.

Elaborate

1. This last scenario takes what they have learned and applies it to a real-life scenario that they may actually find useful one day. In this scenario, a friend from California is trying to take a December ski trip in New Zealand. Students explain why this is a bad idea, using **Patterns** from the task's activities to explain their cause-and-effect reasoning.
    - In their response, students should discuss that this is not a good time to ski in New Zealand because while it is winter in California, it is actually summer in New Zealand. This is because California is in the northern hemisphere and New Zealand is in the southern hemisphere. While there is less direct sunlight on California in December, the tilt of the Earth means there is more direct sunlight on New Zealand in December.

2. We recommend students do this individually as it can serve as a good formative assessment for this task.
    - Collect student work to identify trends in students' ability to use patterns from the stations to explain why there is no skiing in New Zealand in December. See "How to Use This Curriculum" for

strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

5. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.
     - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: models, the sun-earth-moon system, and how they experience celestial phenomena on Earth.
   - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     - **Patterns**: These could be phrases such as, "has in common with" "shares," "is also shown in," "is the same as," "looks the same as," etc.
   - Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 1 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with developing a model of the solar system and proposing the best route a new telescope should take through space. Their prompt is as follows: In order to plan a route through the solar system for the new telescope, you will need to know what it looks like. The best way to imagine what it looks like is to create a model. To prepare you to construct a full solar system model, you have practiced this skill by creating a Sun-Earth-Moon system model. In the process, you have discovered the science behind many things you experience on Earth!
   - Draw a sketch of your Sun-Earth-Moon model with labels.
   - Use your model to describe at least two of the phenomena explored in this task.

- What are the limitations of the model you have drawn? In other words, how does it not accurately represent the Sun-Earth-Moon system?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you were asked to make predictions about the science behind various phenomena. Look back at your predictions: for which ones was your prediction fairly close to the real reason? Pick one where your prediction was far off and write a revised response here.
    - In this task, we focused on the crosscutting concept of **Patterns**: Patterns can be used to identify cause-and-effect relationships. Where did you see examples of **Patterns** in this task?
    - Now that you have learned more about a sub-system of our solar system, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

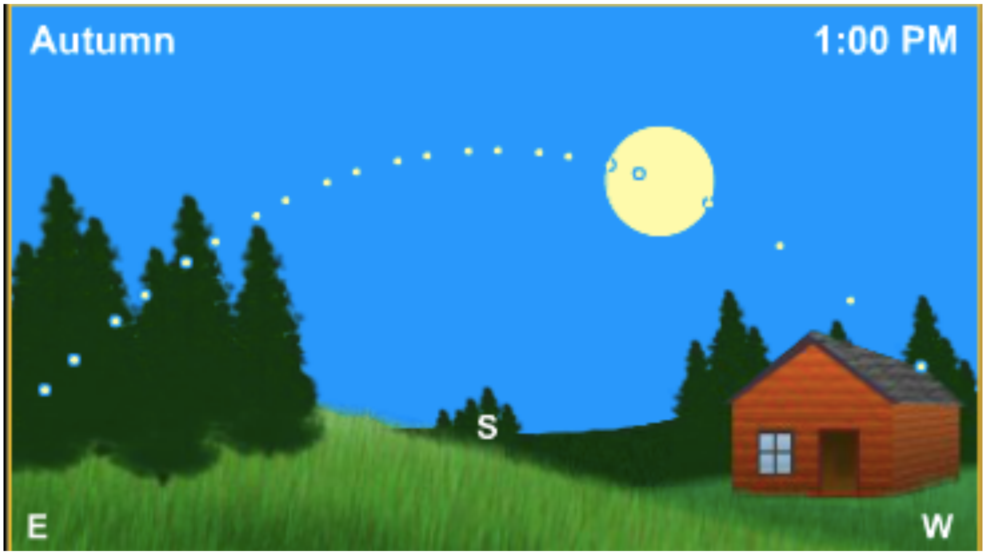
Assessment

1. You may collect students' Project Organizer and assess using:
    - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
    - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
    - Students may make changes to their Project Organizer according to your comments OR
    - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Station Card 1: Sun's Movement Through the Sky

You may have noticed that each day the sun rises and follows an arc through the sky before setting in the evening. Does the sun actually move each day?



Instructions

1. On a computer or ipad, search "Why does the sun rise and set? Mystery Science" in a search engine.
2. Click the top result from mysteryscience.com and select "Start Mystery".
3. Watch the video.
4. Discuss the questions below to help you think about this phenomenon.

Discussion Questions

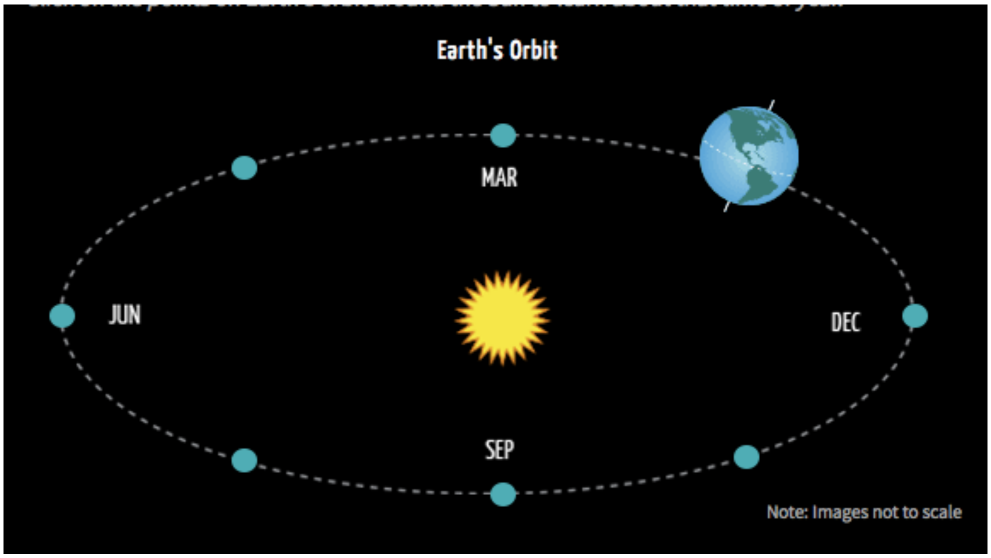
1. What did people previously believe about the movements of Sun and Earth?
2. Is the sun actually moving or are you moving?
3. How can you explain why the sun appears to be moving through the sky during a day?
4. How is the model at the end of this video limited (inaccurate in some ways)?

Sources:

- http://highered.mheducation.com/sites/007299181x/student_view0/chapter2/seasons_interactive.html
- https://mysteryscience.com/astronomy/mystery-1/day-night-earth-s-rotation/73#slide-id-1107

Station Card 2: Seasons

You have also likely noticed that in the United States, it tends to be warmer in the summer and colder in the winter. Why is this the case?



Instructions

1. On a computer or tablet, search "Why do we have seasons? PBS Interactive" in a search engine.
2. Click the top result from pbslearningmedia.org.
3. Launch the interactive.
4. Keep the setting on "New York, USA," but press the small blue circles around Earth's orbit to observe how the sun's angle and path in the sky change throughout the year.
5. Discuss the questions below to help you think about this data.

Discussion Questions

1. Does the Earth stay in one place throughout the year? If not, describe its motion and location in the solar system?
2. Why does the angle of the sun at noon seem to change at different months throughout the year?
   a. How does this create seasons? (Hint: Read the drop-down box entitled "About Seasons" if you are stuck).
3. What do you notice about the angle of Earth?
   a. How do you think this affects the seasons in different hemispheres (halves) of the world? (Hint: keep Earth on December, but click between New York and Melbourne. Notice the difference in sun angle for each location).

Sources:

- https://www.pbslearningmedia.org/resource/npls13.sci.ess.seasons/why-seasons/#.WZsWdZOGPBI

Station Card 3: Shapes of the Moon

You have likely studied the different shapes of the moon you have viewed at night. But what is the reason behind these supposed changes in shape? Replicate the picture below to investigate why.

The following are the parts of your model:

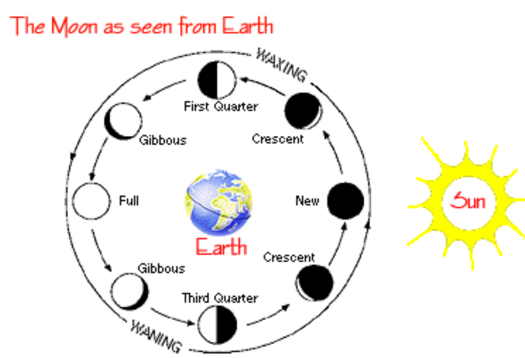
- One group member: Earth
- Styrofoam Ball (on a toothpick, so you can hold it): Moon
- Lamp: Sun

Instructions

1. Have the group member (Earth) turn slowly around in a circle, holding the "moon" out directly in front of them. Then answer the discussion questions below.

Discussion Questions

1. No matter where the moon is in its orbit around the Earth, how much is lit up?
    a. Where does the light source come from?
2. When the moon is between the Earth and the sun, what do you observe from Earth's perspective?
    a. What type of moon do you think this is (Full moon, Crescent Moon, Quarter Moon, New Moon)?
3. When the Earth is between the moon and the sun, what do you observe from Earth's perspective?
    a. What type of moon do you think this is (Full moon, Crescent Moon, Quarter Moon, New Moon)?
4. Does the shape of the moon actually change? If not, what is actually happening?

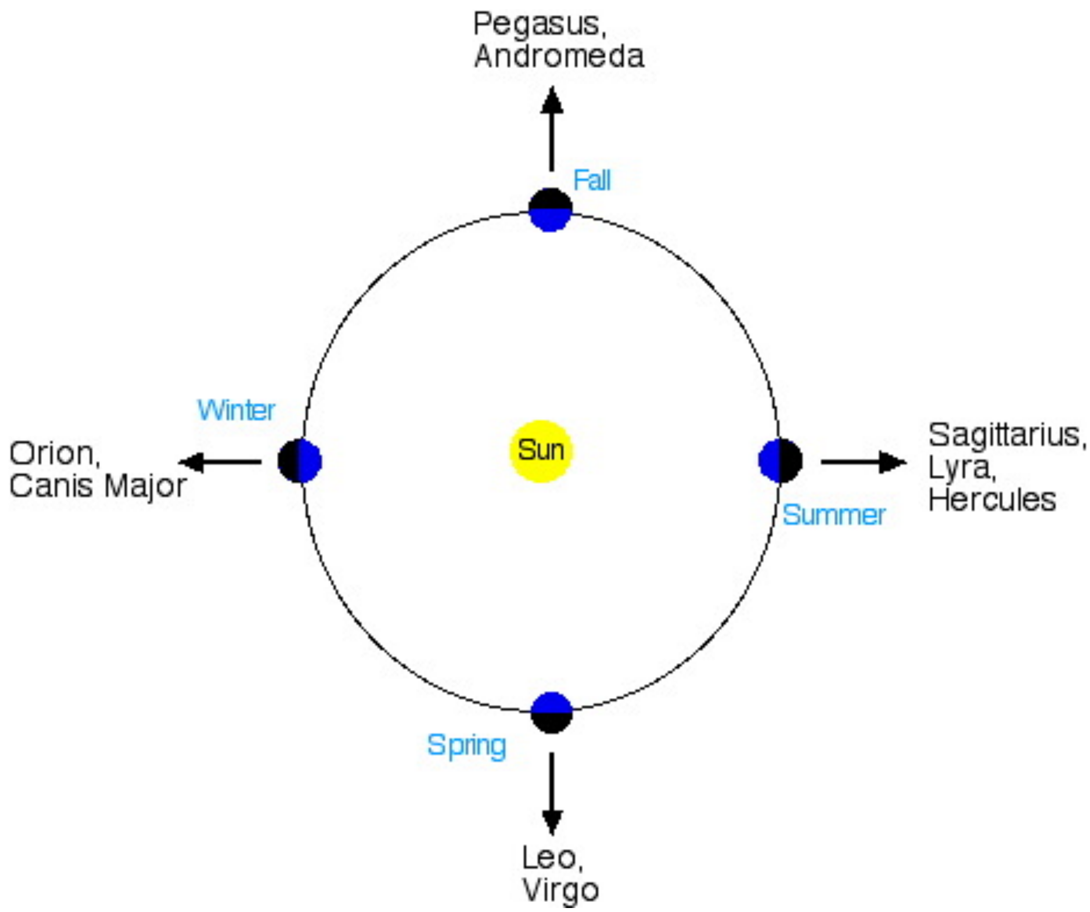


Sources:

- https://www.youtube.com/watch?v=wz01pTvuMa0
- nasa.gov

Station Card 4: Changing Stars in the Sky

You may have looked up in the sky on a winter's evening and noticed that the stars seem different than the ones you would gaze at over the summer. How could this be possible?



Discussion Questions:

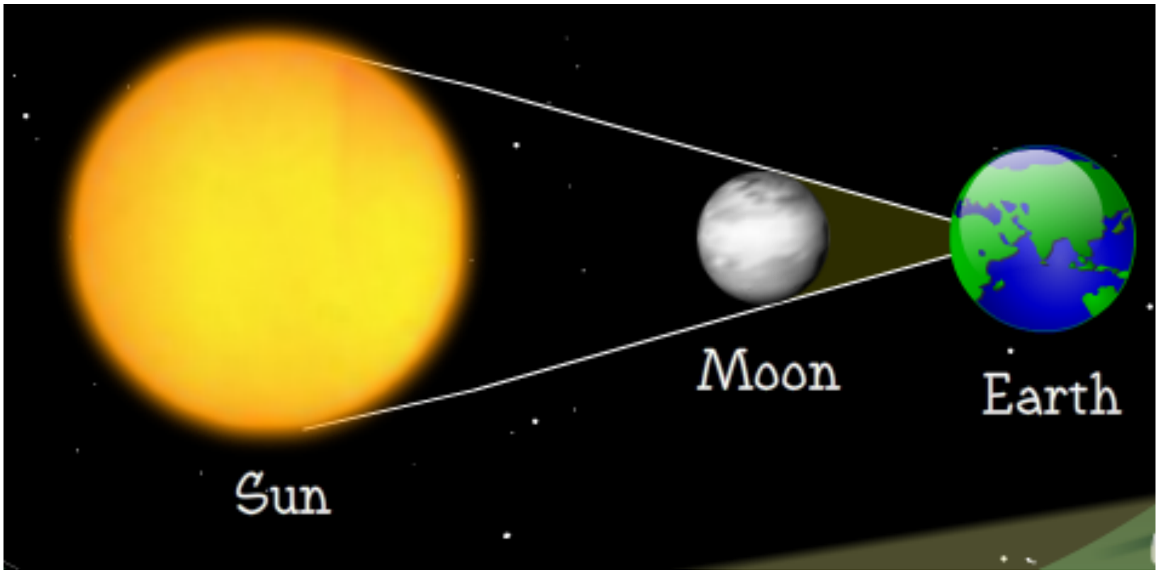
1. Take a look at the image above. On a summer night, what stars are visible? Why do you think those are the ones that are visible?
2. Why wouldn't you be able to see Orion and Canis Major on a summer night? (Hint: at what time of day do you view stars?)
3. Can this phenomenon be explained by the rotation of Earth on its axis OR the rotation of the Earth around the sun? Explain how.

Sources:

- http://curious.astro.cornell.edu/about-us/120-observational-astronomy/stargazing/how-the-motion-of-the-earth-affects-our-view/734-why-do-different-stars-appear-with-seasons-beginner

Station Card 5: Eclipses

You may have seen stories about lunar and solar eclipses on the news. What is an eclipse? How do they happen? And what is the result?



Discussion Questions, Part 1:

1. This picture is not drawn to scale, but helps you to compare the relative sizes of the Earth, sun, and moon. What is the biggest object in this picture?
2. A solar eclipse happens when the sun is completely blocked by the moon. How could that be possible if the sun is so much larger?

Now watch the following video on your computer: "Total Solar Eclipse Animation – PBS Learning Media" and answer the discussion questions below:

Discussion Questions, Part 2:

1. How often does this phenomenon occur?
2. How do the motions of the Earth, Sun, and Moon make this possible?

Sources:

- https://www.meritnation.com/ask-answer/question/explain-solar-eclipse-with-diagram/shadow-and-eclipse/3774143
- https://www.pbslearningmedia.org/resource/ess05.sci.ess.eiu.totaleclipse/total-solar-eclipse-animation/#.WZsZeJOGPBI

8th Grade Science Unit 2: Travelling Through Space
Task 2: A Solar System Model

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction

In the task, students learned that the best way to visualize large systems is to create models. They practiced the skill of developing and using models within the context of the smaller Sun-Earth-Moon system. However, in order to chart a route for the new telescope, they must find out where objects are and how they are laid out within the entire solar system. To visualize all this, students need to develop a model of the solar system, using those skills they practiced in the previous task. Unlike in the last task, however, students now focus on the scale aspect of developing models. To construct a scale model, students must first analyze and interpret data to determine scale properties of objects in the solar system. In doing so, they will find that while the solar system is huge, they can use math to model it on a smaller scale, providing the perfect context within which to plot their telescope route.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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.]*	**Analyzing and Interpreting Data** • Analyze and interpret data to determine similarities and differences in findings.	**ESS1.B: Earth and the Solar System** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids ~~that are held in orbit around the sun by its gravitational pull on them.~~ (The portion of this DCI that is crossed out will be addressed in Task 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.

8th Grade Science Unit 2: Travelling Through Space
Task 2: A Solar System Model

Supplementary Science and Engineering Practices
• Developing and Using Models
  o Develop and use a model to describe phenomena.
  o Evaluate limitations of a model for a proposed object or tool.
• Using Mathematics and Computational Thinking
  o Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.

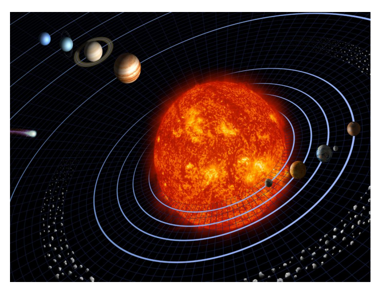
Equity and Groupwork • Discuss how data can create a full picture of our solar system. • Come to consensus to build an assigned planet model.
Language • Use analytical and mathematical terminology to do oral and written analysis of data. • Watch a video and write written conclusions.

Learning Goals

This learning task asks students to analyze and interpret data to determine scale properties of the solar system. More specifically, the purpose is to:

- Explore the idea of scale using a simpler example.
- Analyze and interpret data to determine scale properties of objects in the solar system.
- Use mathematical and computational thinking to scale and build a smaller solar system model.
- Use an example to identify limitations in most solar system models and the importance of scale.
- Apply knowledge of scale properties to explain the layout of the solar system as the backdrop for a telescope route.

Content Background for Teachers



This task builds on what students have already learned about models and the Sun-Earth-Moon system to look at the solar system as a whole. As stated in the background section of the Lift-Off Task, the solar system is made up of eight planets and their moons, along with other smaller celestial bodies. Most students will be able to identify at least a few of these planets. These planets orbit the largest body in the solar system—the sun. Keep in mind that the sun contains 99% of the solar system's mass. Because of this size, it is not reasonable for us to use the same scale for the sun as we do for the planets. This is an important point to emphasize to students as they create their classroom solar system models.

As stated in the background section of the Lift-Off Task, it is the gravitational pull of the sun that keeps all the planets in orbit around it. Each planet orbits the sun at a different distance, known as the orbital radii. The orbital radius is defined as a planet's average difference from the sun. As students will see in the Explore, this distance greatly differs; the greater the orbital radius, the farther it is away from the sun. This is what will allow them to construct a layout of planets in the solar system. Because these distances are so large, scientists use a unit called the Astronomical Unit, or AU, which is approximately 150 million kilometers. It is also important to note that while these numbers tell us of the average distance a planet is from the sun, this does not mean they are all positioned in a straight line. Planets orbit the sun at different speeds, so they will be spread out within the solar system at any given time. This should also be made explicit to students as they develop their classroom models.

Within the same concept of scale properties, students will also learn that planets are different sizes. They will look at data of the diameter of different celestial bodies (including the sun). Some students may need clarification on the term diameter, which measures across the entire center of a sphere, as opposed to radius. Students will find that some planets, like the gas giants Jupiter and Saturn, are much larger than others. And yet, none of these planets come close in size to the sun.

In gaining all this content knowledge through data analysis and development of models, students will better be able to visualize the setting through which they will launch their telescope for their culminating project and truly understand the meaning of a scaled model.

Academic Vocabulary

- Sun
- Earth
- All Other Planets
- Orbit
- Radius
- Astronomical Unit
- Relative (Size/Distance)
- Scale
- Ratio
- Proportion
- Diameter

Time Needed (Based on 45-Minute Periods)

4 Days

- Engage: 0.5 period
- Explore: 1 period
- Explain: 1 period
- Elaborate: 0.5 period
- Evaluate and Reflection: 1 period

Materials

- Unit 2, Task 2 Student Version

Elaborate

- Light source, such as a standing lamp
  - Extension cord, if necessary
- Varied materials to make planet models, such as:
  - Clay
  - Styrofoam spheres
  - Cotton

    - Balloons
    - Construction Paper of different colors
    - Paint and Brushes
- String or Twine
- Rulers (with cm)
- Labels
- Markers

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 2: In the last task, you made a model of the sub-system of the solar system that we are most familiar with, the Sun-Earth-Moon system. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 2: The type of model we made helped us to understand the science behind many phenomena we experience on Earth. The model you will build in this task serves a different purpose. To prepare to launch the new telescope through space, we need to know the layout of the whole solar system *to scale*. As you know, the solar system is huge! If we want to visualize where things are in the solar system, we are going to have to scale objects down, or reduce them to a much smaller size.
    - Now pass out their Task 2 student guide.

3. Before students make a model of the entire solar system to scale, it is important that students understand the idea of scale. This exercise introduces students to the crosscutting concept of **Scale, Proportion, and Quantity**, which they will continue to explore throughout the unit. By introducing the concept within a more familiar context, students will better be able to understand the following idea of scale that is outlined by NGSS: Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small.

4. We recommend students do this individually, as each student will have different examples of locations in their head.
    - You may want to first model the procedure on their student guides via a whole-class demonstration on the board.
    - After students do this activity on their own, debrief the activity and the implications for modeling and scale. In particular, think about how useful one scale might be for certain purposes and not others.
    - Wrap up the activity with the following excerpt from their student guides: Congratulations! You just made your first attempt at a scale model. A scale model shows real objects with all the sizes

reduced or enlarged by a certain amount, known as the scale. Today, you will be exploring the real sizes of objects in the solar system so you can reduce them by a certain amount for your scale model.

Explore

1. In this Explore, students begin to explore the data that will help them to determine scale properties of objects in the solar system.
   - This gives students practice at **Analyzing and Interpreting Data**, as they look at data on planets' diameter and orbital radii to determine similarities and differences among solar system objects.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
   - Ask the Materials Manager to handle any resources needed to complete the task.
   - Ask the Facilitator to read the directions, make sure everyone understands the task, and facilitate discussion.
   - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
   - Ask the Recorder to make sure the group is recording their data analysis in their student guides.

3. Students analyze data showing the diameters of different planets (Part I) and the orbital radii of all the planets (Part II). You may wish to review terms like "diameter" and "orbital radius" before students begin this activity, building off whatever prior knowledge you find most appropriate. Questions are provided on the student guides to facilitate analysis of the data. Some sample student responses are below:
   Part I
   - 1: This illustration shows the planets in relative size. What do you think relative size means? *Relative size means compared to one another's size or in relation or proportion to one another's size.*
   - 2: What is the largest and smallest body in the solar system? *The largest body is the sun, but the largest planet is Jupiter. The smallest body is Mercury.*
   - 3: What do you notice about the size of the planets? Make some comparisons based on similarities and differences you see. *It looks like the first four planets are much smaller than the 5th and 6th planets. The last two planets are average size.*
   - 4: Why does this information matter to create a solar system model and plan a route for the new telescope? *We don't want our telescope to crash into a planet so it is important to know their size in the model.*

   Part II
   - 1: The illustration to the right shows the planets in relative distance from the sun. What do you think relative distance means? *Relative distance means compared to one another's distance or in relation or proportion to one another's distance.*
   - 2: Orbital radius is ultimately the average distance each planet maintains from the sun as it orbits. Why do you think scientists use AU for orbital radii instead of kilometers? *1 AU is 150 million kilometers, so the distance between planets must be huge! That's why you would use AUs instead.*

- 3: Why does this information matter to create a solar system model and plan a route for the new telescope? *We don't want our telescope to crash into a planet so it is important to know how far apart they are in order to maneuver around them.*

4. Optional: Conduct a whole-class debrief that brings out the ideas students saw in the data.
    - The use of equity sticks is encouraged for more equitable participation in class-wide discussions like these (See "How To Use This Curriculum" for more details).

Explain

1. This section of the task asks students to take data they have analyzed and use it to make a physical model of the solar system. This will help them visualize the solar system so they may figure out possible routes the new telescope may take.

2. We recommend reading the two introductory paragraphs on their student guides aloud, as these will give background for why students are making a solar system model and the justification behind the type of model they will make.
    - This activity allows students to explicitly emphasize the crosscutting concept of **Scale, Proportion, and Quantity** as they create a scale model for the solar system, which is much too large to visualize otherwise. Because of the large difference in planet size and planet distance from the sun, it is not realistic for students to use the same scale. Thus, for the sake of this model, they will be using two different scales—one for planet size and one for orbital radii. They will revisit this reasoning in the Elaborate.
    - Students are also continuing to build their skills in **Developing and Using Models**, which they began in Task 1, but are now using to describe the phenomena of our solar system as a whole.

3. Again, we recommend use of group roles in this activity. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Reporter.
    - Ask the Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Reporter to make sure the group is reporting their math and labeling their models.

4. Part I: In this section of the task, students use the following ratios to help them figure out the proportions of their solar system model: Size of Body (1000 km = 1 cm) and Distance from Sun (1 AU = 10 cm)
    - This asks students to use the science and engineering practice of **Using Mathematics and Computational Thinking.** The math is fairly simple and the focus should be on applying the mathematical concept of ratio throughout to ensure a properly scaled model.
    - Optional scaffold: Model the math for each of the charts with "Mercury" so students know how to start.

5. Part II: Assign each group one of the planets to be in charge of for the class solar system model, which they will return to for the rest of the unit.

- Clear a space in your classroom for a class solar system model, placing a light source, such as a standing lamp, in the center of the room. Explain to students that this will represent the sun in their classroom model. They will not be using the same scale for the sun as their planets because the sun is so huge…it takes up 99% of our solar system's mass!
- Provide students with the materials outlined in the beginning of this guide and ask them to use the directions in their student guide to create a physical model of the planet and cut a string to signify the actual distance from the sun. These should then be labeled and placed within the class solar system model (*Note: labeling is essential so the model may be cleared and reassembled for each class period).
- Note: If it doesn't come out naturally as students place their planets, it is important to emphasize to students that while these numbers tell us of the average distance a planet is from the sun, this does not mean they are all positioned in a straight line. Planets orbit the sun at different speeds, so they will be spread out within the solar system at any given time.

Elaborate

1. To drive this idea of *scale* home, students watch the following video detailing the process in creating a truly scaled solar system model: https://www.youtube.com/watch?v=Kj4524AAZdE.

2. Once they watch the video, they will use the questions on their student guide to facilitate a discussion about model limitations and the concept of scale, in pairs. This activity emphasizes a different aspect of the Science and Engineering Practice of **Developing and Using Models** as students evaluate the limitations of various models for the solar system and Sun-Earth-Moon system. Again, students are exploring the crosscutting concept of **Scale, Proportion, and Quantity** by observing an example of a solar system model that is at a different, more accurate scale than their own.
   - In doing so, students will reflect on the models from Task 1 as very limited in their accuracy to scale. Their class solar system model is also limited for several reasons, as described above. First, the sun is far greater than the other planets, so there is not enough room in a classroom setting for an accurate scale. Second, the distance between planets is far greater than the planet diameters, so again an accurate scale cannot be used in a classroom scale. This is why we don't often see true scale models of the solar system. However, the individuals in this video were able to do it by using a huge area (7 miles) and very tiny planets (Earth was just a tiny marble).
   - Debrief the video as a class, using the themes of some of the questions on their student guide. As usual, the use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).

3. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason

for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
  - Draw circles around each question and boxes around each concept.
  - Write connector words to describe connections between the concept boxes.
  - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: layout of the solar system, size of planets, and scale properties of objects in the solar system.
- Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
  - **Scale, Proportion, and Quantity**: These could be phrases such as, "is proportional to", "compared to", "has a ratio of", "is bigger/smaller than", "is longer/shorter than", etc.
- Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 2 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have begun developing a model of the solar system so they can propose the best route a new telescope should take through space. Their prompt is as follows: To plan a route for the new telescope, you will need to know more than just the Sun-Earth-Moon System and more than just a list of total parts; you will need a specific layout. Draw a sketch of your class solar system model, including where the new telescope needs to arrive.
   - In captions, explain the scale you used for your assigned planet within the model.
     - What data did you use?
     - How does it compare to other planets in the solar system model?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you were asked to make a scale drawing showing locations around you. Look back at your drawing: how is this similar to the solar system model you made in this task? What makes your solar system model a better scale model than this first drawing?
   - In this task, we focused on the crosscutting concept of **Scale, Proportion, and Quantity**: scaled models can be used to study time, space, or energy systems that are too large or too small. Where did you see examples of **Scale, Proportion, and Quantity** in this task?
   - Now that you have created a class model of our solar system, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

8th Grade Science Unit 2: Travelling Through Space
Task 3: Gravity in the Galaxies

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction
In the last task, students made a model of the solar system so they could begin to visualize a potential telescope route. However, the parts of the solar system are not stationary…they move! In this task, students will examine what factors affect the motions within the solar system—specifically gravity. Because students have already learned about the concept of gravity in Unit 1, they should be able to build off this prior knowledge and apply it to the solar system as a whole. By using simulation models created from actual solar system data, students will gain a clear picture of how gravity helped to create the solar system and continues to maintain its structure and motion. This will continue to help them develop their telescope route as they consider how gravity might affect the telescope's journey through the solar system.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
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*	**Developing and Using Models** • Develop and use a model to describe phenomena.	**ESS1.B: Earth and the Solar System** • The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. • The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. • All positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference frame and arbitrarily chosen units of size. In order	**Systems and System Models** • Models can be used to represent systems and their interactions.

Earth.]		to share information with other people, these choices must also be shared.	
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.	**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.	**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.	**Systems 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.
Supplementary Science and Engineering Practices • Using Mathematics and Computational Thinking ○ Apply mathematical concepts and/or processes (such as ratio, rate, percent, basic operations, and simple algebra) to scientific and engineering questions and problems.			
Equity and Groupwork • Groups work together to act out models or manipulate simulation models. • Gather and discuss information collaboratively to use in individual writing.			
Language • Discuss gravity models. • Synthesize multiple sources of information. • Describe visual representations in writing. • Write an argument for the effect of mass on gravity and the potential impacts of this on a telescope route.			

Learning Goals:

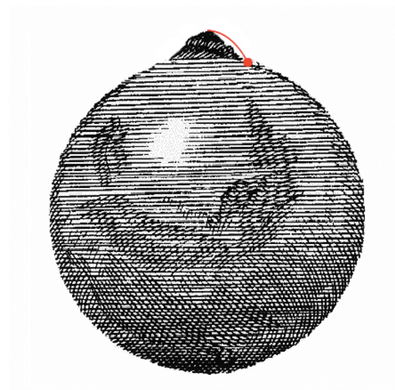
This learning task asks students to use models to describe the role of gravity in the solar system and engage in an argument for the effect of mass on gravity. More specifically, students will:

- Engage in a thought experiment that hypothesizes gravity as the key force in planetary motion.
- Use models to explore gravity's role in the solar system.

8th Grade Science Unit 2: Travelling Through Space
Task 3: Gravity in the Galaxies

- Explain the role of gravity in the motions within the solar system.
- Calculate the rate of falling objects on different planets, dependent on mass.
- Support an argument that the mass of planets affects gravity and thus would impact the telescope route.
- Apply knowledge of gravity and mass to plot a potential route for the new telescope.

Content Background for Teachers



In Unit 1, students moved past their understanding of gravity as merely the force that keeps them on the ground and causes objects to fall. They learned that gravity is a force that attracts objects towards any other bodies with mass. This means that gravity does not just pertain to Earth; it also applies to other planets in the solar system.

In this task, students take this understanding from Unit 1 and push it a little bit farther. They have already been introduced through data and simulations that the mass of an object affects the gravitational pull of that object in a proportional relationship. This task asks them to revisit this idea and the associated pieces of evidence, but contextualized within this unit's culminating project. More specifically, they will end the task by thinking about why understanding the masses and gravitational pulls of different planets is important to charting a safe telescope route through the solar system.

However, just as importantly, students are also now examining the general role of gravity in the motions of bodies in our solar system. This begins with the formation of the solar system. As discussed in the background section of the Lift-Off Task, the solar system was formed when a dense cloud of gas and dust collapsed, forming a swirling disk of material. At the center, it was gravity that pulled more and more material in, causing chemical reactions that released the tons of energy, which birthed the sun. The rest of the matter clumped together, forming larger objects like planets and moons. The rest are part of the asteroid belt.

Because the sun used up 99% of the matter in this event, the sun has the largest mass. This means the sun has the most gravitational pull, explaining why all the planets in the solar system orbit the sun and not the other way around. Each planet orbits the sun because of a balance between the speed in which the planet is moving and gravitational pull of the sun. Each planet is moving at a different speed, but each planet's distance from the sun also varies, causing a different gravitational pull. This balance is what keeps planets in orbits around the sun. The following is an excellent short video explaining how our solar system structure and motions are possible: https://www.youtube.com/watch?v=uhS8K4gFu4s.

For more background in the form of data and computer simulations, see the resources provided to students in their student guide. Also, if students are struggling with basic physics concepts from last unit, refer back to Unit 1 resources and use them to review content with students as needed throughout this task.

Academic Vocabulary

- Speed
- Force
- Gravity

- Orbit
- Mass
- Model
- Rate

Time Needed (Based on 45-Minute Periods)

5 Days

- Engage: 1 period
- Explore: 1 period
- Explain: 1 period
- Elaborate: 1 period
- Evaluate and Reflection: 1 period

Materials

- Unit 2, Task 3 Student Version

Engage

- Computers or Tablets

Explore

- Computers or Tablets
- Rope or string

Explain

- Projector (per class) OR Tablets (per student)
- Stronger Clearer Handout (Optional)

Elaborate

- Labels (1 per group)
- Marker

Evaluate

- Project Organizer Handout

Instructions

Engage

1. Introduce Task 3: In the last task, you made a model of the entire solar system, allowing you to begin to see the different routes the new telescope may take when it is launched. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 3: However, the parts of the solar system are not stationary…they move! In this task, you will explore what factors affect motion within our solar system.
    - Now pass out their Task 3 student guide.

3. Here, students are presented with Isaac Newton's thought experiment, which is known as "Newton's Cannonball." He used it to hypothesize that the force of gravity was universal and is the key force for planetary motion.
    - The first question for students describes Newton's thought experiment. In this thought experiment, Newton visualizes a cannon on top of a very high mountain. He explains that without gravity, the cannonball should logically follow a straight line away from Earth, in the direction it was fired. Students are asked to use their own prior knowledge to hypothesize why this doesn't happen.

4. Students are then given a computer simulation that was made based on "Newton's Cannonball".
    - This offers preliminary practice of **Developing and Using Models** to describe the phenomenon of gravity—a science and engineering practice that they will use throughout this task. This activity thus also introduces students to the crosscutting concept for this task, **Systems and System Models**, as students experience how a model can be used to represent a system and its interactions (in this case focusing on speed and gravity).
    - Students should experiment with the simulation provided in pairs, using the prompts on their student guide.
        - Through this simulation, students should discover that when an object does not have enough speed, the force of gravity pulls the object back down to Earth. When an object has too much speed, it is able to get out of Earth's gravitational field and move away from Earth. At a specific speed, the speed the moon orbits the Earth, students will find that gravity keeps the object in an orbit around the Earth. This is what simulates planetary motion around the sun.
    - Recommended: Ask students to share out their predictions and observations of the simulation. When calling on pairs of students to share their description of a scenario, it is recommended that you call on pairs using equity sticks. This encourages more equitable participation in class-wide discussions.

5. The last question serves to connect their observations from the thought experiment to the solar system as a whole, as well as previous learning about gravity.
    - In Unit 1, they learned about gravity as an attractive force dependent on mass. This question asks students to brainstorm what object in our solar system has the largest gravitational pull and how they think this explains the way objects move in the solar system.
    - Based on the simulation and learning from Unit 1, students should be able to identify the sun as the object with the most mass and gravitational pull. This gravitational pull is the reason why all the planets orbit the sun.
    - Students may discuss and respond to this question in pairs. These questions do not necessarily need to be debriefed class-wide, since they offer a bridge into the next section of the task for continued exploration.

Explore

1. Read the first few paragraphs under the *Explore* header on their student guides aloud. This will transition from the *Engage* to the *Explore* and will set the context for this activity. In groups, students will be exploring models to describe the motion of celestial bodies in the solar system.

- In this section of the task, students are honing their skill of **Using Models**, as they manipulate both physical and computer-based models to describe the phenomenon of how objects move in the solar system. By doing so, they are also emphasizing the crosscutting concept of **Systems and System Models** by considering not just the parts of the solar system that are interacting but also how energy and matter flow within this system to make it function the way it does. Within these models, students will be exploring the interactions between planets and the sun as they relate to speed, mass, and gravitational force.

2. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask the Facilitator to read the directions, make sure everyone understands the task, and facilitate group discussion.
    - Ask the Materials Manager to handle any resources (including computer simulations) needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their responses to the discussion questions for each model.

3. Students are exploring three models, two of which are computer simulations that require computers or tablets.
    - These would be best completed in sequential order as they ask students to build on understandings from the previous models: first, students examine formation of the solar system, then a model of planetary orbit, then a factor that affects solar system movement.
        - Optional: Conduct the first as a whole-class discussion. This both models the process and saves time during the task.
    - As they explore the models, students should be discussing and recording responses to the discussion questions in their student guide. The purpose of these questions is to guide students towards understanding the role of gravity in the motions of celestial bodies.

4. Sample student responses to the discussion questions are shown below:
    - Model 1: Simulating the Formation of Our Solar System
        - What appears to be happening? *Most the matter seems to be getting absorbed into the central body. Other surrounding particles swirl in an orbit, some combining with others to form larger bodies that continue to orbit the central body in one direction.*
        - What does this model imply as the main reason all of the planets orbit the sun? *All of the planets seem to be pulled towards the central body (the sun) by some invisible force (gravity). This causes them to remain in orbit around the sun.*
    - Model 2: Simulating an Orbit with Our Bodies
        - When the rope becomes taut, what happens? *The "planet" person starts to move around the "sun" person.*
        - How does the pull of the rope affect the direction and motion (orbit) of the "planet"? *It makes it orbit around the sun instead of in the direction it originally began*.
        - What do you think the force of the rope pulling on the "planet" represents? *The sun.*

- Model 3: Simulating A Factor That Affects Solar System Movement
  - How does the mass of the Sun impact the orbit of the Earth? Use an example from the simulation. *The mass of the sun keeps Earth in orbit. For example, if the mass of the Sun is increased, the pull will be too strong and Earth will be destroyed in collision with the Sun.*
  - How does the mass of the Earth affect the Moon? Use an example from the simulation. *The mass of the Earth keeps the moon in orbit. For example, if the mass of the Earth is decreased, the pull will not be enough to keep the moon in orbit and it will float away.*
  - We learned in the last unit that mass affects gravitational force. But how does this work in the solar system? Use examples from the simulation to explain how mass affects gravitational force in the solar system. *Mass affects how much gravitational pull a body will have…the greater the mass, the greater the gravitational force. This is what keeps planets in orbit around the sun and moons in orbit around planets. If you change the mass, you risk changing the orbits of different bodies in the solar system.*
  - *Note: This is a revisit of a simulation from Unit 1, so students should be familiar with how to use this simulation.

Explain

1. This section of the task asks students to take what they learned about gravity and motion from all the models and combine it all into one explanation of the solar system as a whole.

2. To lend context and meaning to the task, show the following video that simulates the entire solar system: https://www.youtube.com/watch?v=9R5P9Y9gRYY. Emphasize to students that this was created from authentic data on the solar system. Again, students are practicing the science and engineering practice of **Using Models** to describe the phenomenon of the motion of celestial bodies. By describing parts and interactions of the solar system, they are continuing to emphasize the crosscutting concept of **Systems and System Models**. Student explanations should use evidence from the models and discuss the following:
   - The orbits of the planets,
     - Including what they are all orbiting around
     - And why they are all in orbit
   - Any factors that affect these orbits

3. We recommend students complete this individually as it can serve as a good option for formative assessment. However, students can and should use their group responses to any previous discussion questions to help them formulate an explanation.
   - Once complete, collect student work to identify trends in students' ability to describe a model using evidence OR accurately explain gravity's role in the motion of celestial bodies. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

4. Optional: You may want to use the academic language tool introduced in Unit 1—"Stronger Clearer"—to help students strengthen and clarify language and ideas used to describe the solar system model. As they talk to peers, they can build from others' ideas and borrow language from their partners. This would serve to help solidify basic concepts of gravity and orbits before moving forward.

- This activity can be set up in different ways, but we recommend having students form two concentric circles, so that partners are facing each other.
- A potential guide for students is provided in the box below. As in Unit 1, walk students through the process using the instructions provided on the guide below.

Stronger Clearer: The following activity is to help you and your peers strengthen and clarify your description of the simulated solar system. Each time you talk to a new partner, you can build from their ideas and borrow the language of previous partners.

Instructions:

1. Record ideas and language you liked from your own description in the chart below to help you think about what you will say to your partner (1 minute).
2. Stand in front of your assigned partner. Turn your papers upside down, so that you are not looking at it while speaking. Take turns sharing your description aloud (1 minute per person).
    a. After each partner shares, the listener may ask clarifying questions. Have a discussion about strengths and suggestions (1 minute per person).
3. You will then have time to record any ideas or language that will make your description stronger and clearer (1 minute).
4. When your teacher calls time, each of you in the inner circle will move one space to the right, so you have a new partner. Repeat Steps 2 and 3.

	Ideas and Language I like from the model description
Me	
Partner 1	
Partner 2	

Individually, return to your student guide to write a revised description of the simulated solar system, borrowing from the ideas and language of your peers. Remember that while it is encouraged to learn from others, it is **not** okay to copy directly!

Elaborate

1. This section of the task takes student experience with the last model simulation and connects it to actual data—data they have seen before in their exploration of gravity in Unit 1.

- This data table shows how mass affects gravitational pull, specifically within the context of our solar system.

2. Again, assign roles to each group. We recommend mixing up the group role assignments from the Explore.

3. Ask students to re-examine the data table in their student guides. In this activity, students will be using the science and engineering practice of **Using Mathematics and Computational Thinking**; they apply the mathematical concept of rate to answer the scientific question of whether gravitational attraction depends on the masses of the different planets.
    - While the math is very simple, we recommend you ask students to show their process for at least one rate before using mental math for the rest.
    - As students do so, you may want to check that their mathematical process is correct before letting them repeat their process for all the other rates.

4. Students then return to their solar system model from Task 2 and add some more details that they will need in order to plan their telescope route. Here, they continue the process of **Developing Models**, this time to describe how gravity plays a role in our solar system.
    - Provide each group with a label. Each group will label their original assigned planet with its mass and the rate it takes a rock to fall on that planet.

5. Once students have added to their solar system model, students will argue why adding this information to the solar system model makes it more useful for planning the best route for the new telescope. This asks students to use the skill of **Engaging in Arguments From Evidence**, as they use data evidence and scientific reasoning to support an improved model for our solar system.
    - By engaging in this argument, students will have to use data to argue that mass affects gravitational attraction in the solar system and this must be considered as the telescope passes different planets in its journey through space.
    - Students should use data from the data table and likely Model 3 as evidence to justify their argument.
    - Again, you may wish to have students complete this question individually, so it may be used as a formative assessment. Once complete, collect student work to identify trends in students' ability to support an argument with evidence OR accurately explain how gravitational attraction depends on the mass of objects. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

Sample Argument	Optional Sentence Stems
Adding the masses of all the planets makes our model more useful because we now know that the mass of an object affects its gravitational attraction. Gravity can pull objects, like the new telescope, towards planets that have a lot of mass, so it is essential we know about the masses of the planets. Model 3 provided evidence of this: when I increased the mass of the Earth, the gravitational pull	○ Adding the masses of all the planets makes our model more useful because… ○ In order to plan the best route for the new telescope, we need to know… ○ If mass ____, then gravitational

increased, causing the moon to collide with Earth. We do not want this to happen with the new telescope. The data table also showed us that as planet mass increases, the rate of the falling rock increases, meaning gravity increases. For example, the rate for the Earth is 22.17 m/s, while Mercury, which has smaller mass, is only 13.62 m/s. We would have to stay farther away from Earth than Mercury to avoid the pull of gravity.	pull ___. ○ Model 3 provided evidence of this when… ○ The data table showed us that… ○ For example… ○ This means that the route for the new telescope would have to…

6. Return to the whole-class concept map from the Lift-Off Task.
    - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
        - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
        - Draw circles around each question and boxes around each concept.
        - Write connector words to describe connections between the concept boxes.
        - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: the creation of our solar system, the role of gravity in how objects move in our solar system, and the relationship between mass and gravity.
    - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concept as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
        - **Systems and Systems Models**. These could be phrases such as, "is a part of" "connects to," "interacts with," "is made up of," "works together with," etc.
    - Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 3 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have developed a model of the solar system and will now begin to brainstorm the best route a new telescope should take through space. The student prompt is as follows: Even though you already have the layout of the solar system, you now know that these objects don't just remain stationary…they move because of gravity! Based on what you've learned about mass, gravity, and motion, draw a potential route for the new telescope on the sketch you made in the Task 2 section. Then in this section:
    - Explain why the solar system is laid out the way it is: what is the role of gravity in the solar system?
    - Use your model and data from the task to explain how gravity might affect the new telescope as it moves through space.
    - Justify your route by explaining why you stay farther away from some planets, but not others.

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
    - At the beginning of this task, you used a thought experiment to think about why planets might move the way they do in our solar system. Look back at your responses: after learning everything you have about gravity, how would you add to or revise your responses? Use information from the models to improve your explanation of Newton's thought experiment.
    - In this task, we focused on the crosscutting concept of **Systems and System Models**: models can be used to represent systems and their interactions. Where did you examples of **Systems and System Models** in this task?
    - Now that you have used and developed models to describe the movement of celestial bodies in our solar system, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

Assessment

1. You may collect students' Project Organizer and assess using:
    - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
    - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
    - Students may make changes to their Project Organizer according to your comments OR
    - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

8th Grade Science Unit 2: Travelling Through Space
Task 4: Invisible Forces

Unit Essential Question: *What forces keep the parts of our solar system together and how can we use this knowledge to plot a telescope route through space?*

Introduction

In the last task, students explored one invisible force—gravity—specifically looking at the role it plays in the motion of celestial objects in our solar system. In doing so, they were able to add to their visualization of the solar system as a whole, providing a rich context within which to plan their new telescope route. In this task, students examine another invisible force—magnetism—but more to think about how to protect the telescope itself as it travels through space and how it will then behave as a result. Students often conceive of magnetism as this invisible mystery force that makes objects appear to move on their own. To learn more about these invisible forces and fields, students will need to conduct investigations, analyzing and interpreting data to prove that these fields do indeed exist and can explain the phenomena they see. By the end of this task, students will not only be able to make some recommendations to create a strong magnetic field that protects their telescope, they will also be able to predict the subsequent behavior of the telescope due to its magnetic field.

Alignment Table

Performance Expectations	Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts
MS-PS2-3. Ask questions about data to determine the factors that affect the strength of electric and magnetic forces. [Clarification Statement: Examples of devices that use electric and magnetic forces could include electromagnets, electric motors, or generators. Examples of data could include the effect of the number of turns of wire on the strength of an electromagnet, or the effect of increasing the number or strength of magnets on the speed of an electric motor.] [*Assessment Boundary: Assessment about questions that require quantitative answers is limited to proportional reasoning and algebraic thinking.*]	**Asking Questions and Defining Problems** • Ask questions that can be investigated within the scope of the classroom, outdoor environment, and museums and other public facilities with available resources and, when appropriate, frame a hypothesis based on observations and scientific principles.	**PS2.B: Types of Interactions** • Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects.	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.

8th Grade Science Unit 2: Travelling Through Space
Task 4: Invisible Forces

MS-PS2-5. Conduct an investigation and evaluate the experimental design to provide evidence that fields exist between objects exerting forces on each other even though the objects are not in contact. [Clarification Statement: Examples of this phenomenon could include the interactions of magnets, electrically-charged strips of tape, and electrically-charged pith balls. Examples of investigations could include first-hand experiences or simulations.] [Assessment Boundary: Assessment is limited to electric and magnetic fields, and is limited to qualitative evidence for the existence of fields.]	**Planning and Carrying Out Investigations** • Conduct an investigation and evaluate the experimental design to produce data to serve as the basis for evidence that can meet the goals of the investigation.	**PS2.B: Types of Interactions** • Forces that act at a distance (electric, magnetic, and gravitational) can be explained by fields that extend through space and can be mapped by their effect on a test object (a charged object, or a ball, respectively).	**Cause and Effect** • Cause and effect relationships may be used to predict phenomena in natural or designed systems.
MS-PS3-2. Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system. [Clarification Statement: Emphasis is on relative amounts of potential energy, not on calculations of potential energy. Examples of objects within systems interacting at varying distances could include: the Earth and either a roller coaster cart at varying positions on a hill or objects at varying heights on shelves, changing the direction/orientation of a magnet, and a balloon with	**Developing and Using Models** • Develop a model to describe unobservable mechanisms.	**PS3.A: Definitions of Energy** • A system of objects may also contain stored (potential) energy, depending on their relative positions. **PS3.C: Relationships Between Energy and Forces** • When two objects interact, each one exerts a force on the other that can cause energy to be transferred to or from the object.	**Systems 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.

static electrical charge being brought closer to a classmate's hair. Examples of models could include representations, diagrams, pictures, and written descriptions of systems.] [*Assessment Boundary: Assessment is limited to two objects and electric, magnetic, and gravitational interactions.*]			

Supplementary Science and Engineering Practices

- Analyzing and Interpreting Data
  - Analyze and interpret data to determine similarities and differences in findings.

Equity and Groupwork

- Work in specific group roles to conduct experiments.
- Come to consensus on questions to investigate.
- Work together to plan and conduct an exploration.

Language

- Record observations.
- Write lab conclusions based on data.
- Ask questions related to data.
- Depict scientific concepts in a model.

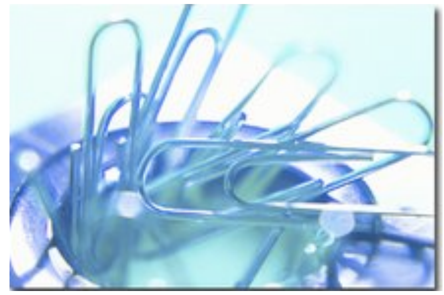
Learning Goals

This learning task asks students to gather evidence that magnetic fields exist at different strengths, caused by different factors. More specifically, the purpose is to:

- Make predictions about a mysterious phenomenon.
- Conduct investigations about invisible forces.
- Use data as evidence for the existence of fields between objects not in contact with each other.
- Use cause and effect relationships to predict how objects not in contact with each other may behave.
- Evaluate an experimental design.
- Ask questions about data and conduct an exploration to determine the factors that affect the strength of magnetic fields.
- Complete a model to illustrate the relationship between arrangement of magnets and potential energy in a magnetic system.
- Apply knowledge of magnetic fields to create a protective magnetic field around the new telescope and predict the behavior this will cause.

Content Background for Teachers

This task exposes students to a new non-contact force – magnetic force. Specifically students begin to learn about magnetic fields, or the areas where an object exhibits a magnetic influence. For students, these are the invisible forces and fields that can explain why objects not in contact can do things like "float" and move away from each other.



Most students will come to this lesson with a basic experiential understanding of magnets. For example, they might know that magnets can attract or repel depending on the "sides" put together. They might also know that not all materials are attracted to magnets, just some. These ideas will be reaffirmed in Station 1 of the Explore, solidifying that there is some invisible force at play, but only between some objects.

Something that students may not be familiar with is a magnetic field. Around every magnet, there is an invisible field called a magnetic field. This field is what attracts items, like paper clips and nails to the magnet. In magnetic fields, objects are affected along things called magnetic field lines. Magnetic poles are the points where the magnetic field lines begin and end. For example, the poles on Earth are where our planet's field lines originate and come together. Although the magnetic field is invisible, an experiment with iron filings in the Explore can indicate where it is because the iron filings line up with the field.

When students conduct experiments about these magnetic fields, they will find that the field lines will be different depending on the type of magnet used. They will also see that the field lines spread out from the north pole and circle back around to the south pole, but the iron filings tend to concentrate at the poles because that is where the field is the strongest. While these are great two-dimensional visuals for students, it is important to emphasize that magnetic fields are really three-dimensional.

Students also start to experiment with electromagnets in the last lab station of the Explore. Unlike permanent magnets, this station uses non-magnetized metal connected to a wire conducting electric current. This, in turn, generates a magnetic field. In the lab, students will notice that a wire-wrapped nail alone does not attract paperclips. However, once connected to a battery, the wire-wrapped nail can attract paperclips.

This same lab station also allows students to begin to think about what factors affect the strength of a magnetic field. Increasing the coils of a wire will strengthen the magnetic field. Increasing the strength of the battery will also strengthen the magnetic field. More simply, decreasing the distance between a magnet and magnetic object will increase the magnetic field. Something else to consider is that only some materials are magnetic—materials like iron, steel, nickel, and cobalt.

The last concept students explore in this task is how the arrangement of objects interacting at a distance can affect the different amounts of potential energy stored in a system. While this can be related to many scenarios, it also can be applied to magnetism. In any system of magnets, there is magnetic potential energy, the amount of which depends on how the magnets are arranged with respect to each other. When the magnets are rearranged, this magnetic potential energy can change. If the magnetic potential energy increases, then the kinetic energy of the objects in the system will decrease, and vice versa. For example, when two carts with magnets attached push each other apart, there would be a decrease in magnetic potential energy and an increase in kinetic energy.

8th Grade Science Unit 2: Travelling Through Space
Task 4: Invisible Forces

Academic Vocabulary
- Magnet
- Orient
- Battery
- Magnetic field
- Kinetic Energy
- Potential Energy
- Attraction
- Repulsion

Time Needed (Based on 45-Minute Periods)
4.5 – 6.5 Days
- Engage: 0.5 period
- Explore: 1-2 periods
- Explain: 1 period
- Elaborate: 1-2 periods
- Evaluate and Reflection: 1 period

Materials
- Unit 2, Task 4 Student Version

Engage
- Projector and Computer

Explore
- Station Cards 1-4 (2 copies for each station)
- Station 1
    - 2 Bar magnets
    - Various objects of different materials, some magnetic and some not
- Station 2
    - Paper clip
    - Piece of Thread
    - Tape
    - Small bar or horseshoe magnet
- Station 3
    - Ziploc Bag
    - 3x5 index cards
    - Iron filings
    - Paper Clip
    - 2 Bar Magnets
- Station 4
    - 5 feet insulated copper wire
    - 6-volt battery
    - D-size battery

- Large iron nail
- Paper clips

Explain
- Critique, Correct, and Clarify Handout (Optional)

Elaborate
- All materials from the Explore (one set of all materials for each group)

Evaluate
- Project Organizer Handout

Instructions

Engage

1. Introduce Task 4: In the last task, you thought about one non-contact force that may affect your telescope route—gravity. Think about what you were still wondering about at the end of the last task (look back if you need to). What questions do you still have?
    - Before you pass out their student guide, give students time to reflect individually or with a partner about the questions they recorded at the end of the last task. Share a few of these out as a class, using facilitating questions to guide students toward questions that relate to this task.

2. Transition to Task 4: Throughout this unit, you have thought a lot about the solar system as a whole in order to inform your decision on the best route for the new telescope. To ensure a successful mission, we also need to think about the telescope itself. Today we are going to learn about another non-contact force so we can better understand how the new telescope will behave in space and how we can protect it while in space.
    - Now pass out their Task 4 student guide.

3. Unlike contact forces from last unit, the forces students are studying today are invisible to students, making the concepts all the more difficult to grasp. To introduce students to these invisible forces, have them watch the following video: https://www.youtube.com/watch?v=LLIIYtnDups.
    - When projecting the video, make sure that students do not see the title of the video, as we don't want to reveal the term "magnetism" just yet.

4. After students watch the video, have them discuss the questions that follow in pairs. These questions ask them for both observations and a prediction for how it is possible that objects seem to be floating and moving on their own.
    - Emphasize to students that there is no right answer and that this is a prediction that they will build on throughout the task.
    - Share out a few responses to the questions using equity sticks (See "How to Use This Curriculum" for more information).

Explore

1. In this activity, students engage in the practice of **Planning and Carrying Out Investigations**, as they conduct investigations to produce data that can serve as evidence that magnetic fields do exist. Based on

their observations, students then analyze the data for similarities and differences, which will help them figure out that objects that aren't touching each other behave in this way because of magnetic fields. Thus, students are also engaging in the practice of **Analyzing and Interpreting Data.**

2. Set up four stations around the room with the materials outlined in the Materials section and copies of the station cards. For large class sizes, we recommend making two of each station so the amount of students at each station allows for all students to engage.

3. Assign roles to each group. You may use whatever roles you prefer. We recommend the use of the Materials Manager, Facilitator, Harmonizer, and Recorder.
    - Ask the Facilitator to read the directions and to make sure everyone understands the task.
    - Ask the Materials Manager to handle any resources needed to complete the task.
    - Ask the Harmonizer to make sure that everyone contributes their ideas and that everyone's voice is heard.
    - Ask the Recorder to make sure the group is recording their observations and analysis in their student guides.

4. Give students a set amount of time with each station. We recommend at least 10 minutes per station for students to really explore and process.
    - As students conduct the four experiments outlined in the station cards, they should be recording their observations and drawings, and answering the discussion questions in their student guides.
    - The purpose of the discussion questions is to guide data analysis. You will notice students using language and drawing diagrams relating to the crosscutting concepts of **Cause and Effect** and **Systems and System Models**, as students think about the interacting parts of a magnetic system, particularly how different factors affect the flow of energy and matter in these invisible fields.

5. Below is an outline of the four stations as well as a sample Data Analysis Chart.
    - Station 1 - Exploring Invisible Forces: This station introduces students to the basics of magnets—attraction vs. repulsion and the different types of materials that are attracted to magnets.
    - Station 2 – Testing the Strength of an Invisible Force: This station gives students more exposure to a field between objects not in contact, but adds the effect of distance on the strength of the magnetic force.
    - Station 3 – Exploring Invisible Fields: This station allows students to see the actual pattern of the different magnetic fields, represented with iron filings.
    - Station 4 – Creating Invisible Fields: This station shows students how magnetic fields are created with electricity and allows them to experience with factors that affect the strength of the field (number of coils, battery size).

Sample Data Analysis Chart

	Observations and Drawings	**Discussion Questions**
Station 1: Exploring Invisible	*I noticed that when you put one side of the bar magnets together, they attract, but when you put them the*	1. How did orienting the two magnets different ways affect how they moved? Why do you think this happened?

8th Grade Science Unit 2: Travelling Through Space

Task 4: Invisible Forces

Forces	*other way, they push away from each other. I also noticed that only some objects move towards the magnets and others do not.*	*When oriented one way, the magnets moved towards each other. When oriented the other way, the magnets moved away from each other. I know from previous science classes that there are positive and negative sides to a magnet. When like sides are together, they repel. When opposite sides are together, the attract.* 2. What conclusions can you make about the different objects tested? *Only metal objects seemed to be attracted to the magnet, specifically…(answers will vary based on objects provided).* 3. Do all objects have this "invisible force" acting on them? If not, which ones? *No, only some objects, the ones stated above.*
Station 2: Testing the Strength of an Invisible Force	*I observed some invisible force attracting the metal paper clip to the magnet. This only worked when the paper clip was close enough to the magnet; otherwise it would fall.*	1. How do you think the magnet is able to move the paper clip without touching it? *There is an invisible force that attracts the metal paper clip to the magnet.* 2. Is the magnet always able to move the paper clip? If not, what factor affects when the magnet can move the paper clip or not? *No, sometimes the paper clip falls. This happens when the magnet is placed too far from the paper clip. Distance is the factor that affects magnet strength.*
Station 3: Exploring Invisible Fields	*I observed nothing to happen when the iron filings were placed on the paper clip. However, when the iron filings were placed on different magnets, they formed different patterns, all coming out of two points and connecting to each other.*	1. The fields we have been exploring are invisible, but the iron filings allow us to see the pattern of the field. How did these filings differ in the different scenarios you conducted above? *They differ depending on the type of magnet (descriptions will vary based on types of magnets provided).* 2. Where do you see the most filings? This is where the field is the strongest. *At the ends (poles)*
Station 4: Creating Invisible Fields	*I observed that the wire-wrapped nail alone could not pick up any paper clips, but once the wire was connected to a battery, it could. When we added more coils or increased the battery strength, the nail could pick up even more paper clips.*	1. Does the invisible force exist between just the wire-wrapped nail and the paper clips? *No.* 2. How were you able to create the invisible force between the wire-wrapped nail and the paper clips? *We connected the ends of the wires to two ends of a battery.* 3. What factors do you think might affect the

		strength of the invisible force? *Answers will vary, but students may later investigate the amount of coils in the wire and the type of battery.*

6. Optional: Conduct a class-wide discussion outlining the main things students learned from each of the lab stations.
    - Again, we recommend use of equity sticks when calling on students to create a more equitable discussion (See "How to Use This Curriculum" for more details).

Explain

1. Now that students have collected lab evidence of magnetic forces and fields, it is time for them to put all this evidence together. In this section, students answer a series of lab questions in pairs to draw conclusions about what the data shows, explain how this conclusion can be used to predict the behavior of other similar scenarios, and to evaluate the experiments.

2. For question 1, students are asked to write a conclusion based on multiple lab experiences. Below is a sample of an advanced response, as well as optional sentence frames to provide students for language support:
    - Advanced Sample Student Response: Invisible fields exist between some objects not in contact with each other, creating forces that cause objects to look like they are moving on their own. In Station 1, when two magnets are placed close together or a magnet is placed near a metal object, they are attracted together. When two magnets are placed close together with the opposite orientation, they are repelled apart. In Station 2, a magnet can make a paper clip "float," but only at a certain distance apart. In Station 3, when iron filings are placed on a magnet, they form a pattern that represents this invisible field. In Station 4, when the wire around a nail is connected to a battery, the nail is able to attract metal paper clips. All of these examples from the labs are evidence that there is an invisible field that exists between some objects, mainly magnets. The field causes some force to be exerted on the objects, such as attracting certain objects or repelling certain objects. This explains why we see objects "floating" or moving on their own. According to the evidence, this only seems to be the case at a certain distance and for certain substances.
    - Optional Sentence Frames
        - Lab Conclusion:
            - ____ causes the interactions we see between objects not in contact with each other.
            - Objects not in contact with each other can sometimes appear to ___. This is because there are…
        - Evidence and Reasoning
            - In Station 1, when ____, this causes ____.
            - In Station 2, a magnet can…
            - In Station 3, when ____, this causes ____.
            - In Station 4, when ____, this causes ____.
            - All of these examples from the labs are evidence that…

        - In each of these pieces of evidence...
        - The field causes…
        - This explains why we see…
        - According to the evidence, this only happens when…
    - You may wish to highlight the writing skill of incorporating evidence, using the "Critique, Correct, and Clarify" language strategy. First, have students read the prompt in pairs. Then provide students with the following template to do a "Critique, Correct, and Clarify" focusing on the incorporation of evidence. We recommend having them do their analysis of the sample individually, then discuss and write an improved explanation in pairs, and debrief their reasoning as a class.
        - Once complete, collect student work to identify trends in students' ability to draw conclusions using lab evidence. See "How to Use This Curriculum" for strategies on utilizing formative assessment data to provide feedback to students and inform classroom instruction.

Critique, Correct, and Clarify: Interactions Between Distant Objects In pairs: 1. Critique: Analyze the response for how well it incorporates **evidence**. *1. Invisible fields exist between some objects not in contact with each other, creating forces that cause objects to look like they are moving on their own.* *a. I know this because in the stations, objects would be attracted to each other or repelled away from each other even though they weren't touching. Sometimes, you could even use materials to visualize the field. This proves that there are fields between objects and explains why objects appear to float or move on their own.* 2. Correct: Write an improved explanation in your student guide. 3. Clarify: Describe how and why you corrected the response.

3. For question 2, students are asked to write some general rules about how objects not in contact can interact based on what they experienced in the investigations.
    - This emphasizes the crosscutting concept of **Cause and Effect** as students use cause-and-effect relationships they have identified in the labs to predict how other objects may behave in similar circumstances.
    - Students will write a variety of rules, but below is a list of possible student responses:

    - When you put two magnets together, sometimes they attract and sometimes they push away, depending on the side.
    - Only some materials are attracted to magnets, such as iron and nickel.
    - Magnetic fields only attract objects for a certain distance.
    - Magnetic fields are strongest at the poles.
    - Magnetic fields can be created with electricity.
    - The strength of a magnetic field depends on certain factors.
  - You may wish to provide some sentence frames:
    - When you put two magnets together…
    - Only some materials…
    - Magnetic fields can…
    - Magnetic fields are strongest…
    - Magnetic fields can be created by…
    - The strength of a magnetic field depends on…
    - Magnetic fields only…

Elaborate

1. In the Explore, students started to test factors that affect the strengths of magnetic fields. This Elaborate asks groups of students to take that exploration a bit further. This will be crucial to their culminating project, as they will be asked to make recommendations for a protective magnetic field around the telescope.
    - At this point, introduce students to the term of <u>magnetic fields</u>, and explain that this is what scientists call the invisible fields students have been exploring throughout this task.

2. Question 1 asks students to evaluate the investigation for whether it was able to produce the data needed to conclude what factors affect the strength of magnetic fields. This aligns with one aspect of the science and engineering practice of **Planning and Carrying Out Investigations**.

3. Question 2 has students look back at data from Stations 2 and 4. From that data, they should make a list of questions they still need to ask in order to determine what factors affect the strength of magnetic fields.
    - These could be questions such as: How do we know when the magnetic field is strong? What materials are more attracted to the magnets and what materials are not attracted? How does the size of the battery affect the strength of the magnetic field? How does the number of coils in the wire affect the strength of the magnetic fields?
    - We recommend having students first generate questions as a group, but then share them all out to create a class list. This can lead to a discussion of how they might go about testing some of these questions.
    - This activity gives students specific practice in the science and engineering practice of **Asking Questions** as they attempt to determine the factors that affect the strength of electric and magnetic forces and frame a hypothesis based on their observations.

4. Question 3 has students use their questions to do a small exploration, using all the materials from the lab stations. They will be able to put their questions to the test and then draw some conclusions that will inform their recommendations for the new telescope. For a more traditional approach, you may wish to collect the main questions from the discussion above and run these investigations as class-wide demonstrations.
    - For factors that increase the strength of a magnetic field, students will identify things like increasing the number of wire coils, increasing battery voltage, or using objects that have magnetic materials like iron, copper, nickel, cobalt, or steel.

5. Question 4 asks students to apply these conclusions to the protection of their telescope. In doing so, students are using identified cause-and-effect relationships to predict how a strong magnetic field can be created. This specifically emphasizes the crosscutting concept of **Cause and Effect.**

6. Question 5: In exploring how different materials and magnets interact, students will also be experimenting with the arrangement of magnets. This question links old concepts of kinetic and potential energy to magnetic systems. In every magnetic system, there is magnetic potential energy, which depends on how the magnets are arranged with respect to each other. Here, students will use lab observations to complete the model provided. When magnets are pushing each other apart, there is a decrease in potential energy and an increase in kinetic energy. When magnets are attracting towards each other, there is an increase in potential energy and a decrease in kinetic energy.
    - This gives practice at **Developing and Using Models** to describe unobservable mechanisms while also emphasizing the crosscutting concept of **Systems and System Models** as students complete a model to show interactions and energy flow within a magnetic system.
    - While students should discuss these questions with their group, we highly recommend debriefing as a class, as these are complex concepts.

7. Question 5 asks students to put these concepts together and take it a little further to apply to their culminating project. Once the telescope has a magnetic field, it will then interact with planets that have magnetic fields. Here students make a prediction of how the telescope might behave as it passes planets with magnetic fields.
    - Because they understand attraction and repulsion, they should make some prediction about the telescope spinning and changing its orientation.

8. Use one or both of the following resources to solidify these concepts with students:
    - https://www.windows2universe.org/physical_science/magnetism/bar_magnet_interactive.html: This interactive shows a bar magnet and a compass, but can be used to represent a planet with a magnetic field and the new telescope: Keep the bar magnet (planet with magnetic field) in one place and move the compass (the new telescope) on a route past the bar magnet. Ask students to notice how the telescope behaves as it moves past the planet. Students should hypothesize that their new telescope will spin as it moves past planets with magnetic fields.
    - https://www.youtube.com/watch?v=G_uKt2i2jvc: This video does a great job at summing up everything students have learned about magnetism. Like the interactive above, it also helps students to see that their telescope will likely spin as it moves past planets with magnetic fields.

- After students engage with these resources, you may want them to revisit their responses to Question 5.

9. Return to the whole-class concept map from the Lift-Off Task.
   - In small groups, have students brainstorm new concepts and new connections that they have learned in this task, as well as any new questions that have come up for them. Then have groups share these aloud in a class-wide discussion and add to the class concept map. The use of equity sticks is encouraged for more equitable participation in class-wide discussions (See "How To Use This Curriculum" for more details).
     - Some facilitating questions to ask students are: What new ideas/concepts do you want to add to the map? What connections do you want to add or change? What is your reason for that addition/revision? What connections can we make between the questions/ideas already on the map? What new questions do you have about the phenomenon?
     - Draw circles around each question and boxes around each concept.
     - Write connector words to describe connections between the concept boxes.
     - For this task, students may begin to connect some of their previous question circles to concept boxes about the following: another non-contact force—magnetic fields.
   - Have students analyze the additions to the class concept map for as many examples of this task's crosscutting concepts as they can find. Once a student has identified the crosscutting concept, you can trace the circle in the corresponding color (decided on in the Lift-Off task). We recommend asking students to share key words that helped them identify the crosscutting concept for that concept or question. Some identifying words students might look for are:
     - **Cause and Effect**. These could be phrases such as, "which results in," "which causes," "that explains why," "is due to," etc.
     - **Systems and Systems Models**. These could be phrases such as, "is a part of" "connects to," "interacts with," "is made up of," "works together with," etc.
   - Once again, the purpose of this concept map is to facilitate generation of student questions, promote language development, and support understanding of the science content throughout the unit. Allowing students to ask their own questions and use their own words to make meaning of the concepts will not only help them make deep connections about science content, but will also help their oral and written language development.

Evaluate: Connecting to the Culminating Project

1. Students independently complete the Task 4 section of the Unit 2 Project Organizer in class. Revisions can be done for homework, depending upon student's needs and/or class scheduling.

2. Students have been tasked with developing a model of the solar system and proposing the best route a new telescope should take through space. Their prompt is as follows: We need to protect the new telescope from solar wind as it travels through space. Scientists say that the new and best protection is to create a magnetic field around the telescope. But how do we do this? Use what you have learned to make some recommendations for a protective magnetic field.

- How will we know a magnetic field has been created? We can't see them, so what evidence is there that magnetic fields exist?
- What kinds of factors affect the strength of magnetic fields?
  - What questions did you have to investigate to find out this information?
- Research magnetic fields on different planets. Based on what you learned about arrangement of objects and potential energy, how might the telescope be affected as it passes these different planets?

Reflection

1. At the end of the task, ask students to reflect on what they have learned over the course of this task by answering the following three questions in their student guide:
   - At the beginning of this task, you made predictions for how objects could possibly float and move without touching them. Look back at your initial prediction: after learning everything you have about magnetic forces and fields, how can you add to your prediction?
   - In this task, we focused on the crosscutting concepts of **Cause and Effect**: cause and effect relationships may be used to predict events, and **Systems and System Models:** models can be used to represent systems and their interactions. Where did you examples of **Cause and Effect** and **Systems and System Models** in this task?
   - Now that you have learned about the role of magnetic fields in your telescope route, what questions do you still have?

2. There are no right answers, but encourage students to look back at their student guides and their class concept map. They should not change their initial responses, but rather use this reflection space to add to their ideas and questions based on what they have learned through this task. By generating more of their own questions, students continue to engage in sense-making of the phenomenon and gathering knowledge and skills for their final projects.

<u>Assessment</u>

1. You may collect students' Project Organizer and assess using:
   - *Criteria of your choice.* We recommend using the 3-Dimensional Assessment matrix at the beginning of this document to inform your criteria.
   - This can be a formative tool to periodically look for trends in student understanding after the completion of a task. You can then use this formative data to inform any re-teaching as necessary.

2. You may also give students time to make revisions with one of the two options:
   - Students may make changes to their Project Organizer according to your comments OR
   - Ask students to exchange Project Organizers with a partner and give partners 5 minutes to give written feedback. Then allow students time to make changes to their work according to the feedback.

Station 1: Exploring Invisible Forces

Materials

- 2 Bar magnets
- Various objects of different materials

Procedure

1. Take both magnets and manipulate them in different ways, putting different sides together. Record your observations.
2. Study the objects provided and group them based on what you know about the materials. Which do you think will be attracted to a magnet. Why?
3. Test each object by bringing one magnet closest to it. Record your results in your student guide.

Discussion Questions

1. How did orienting the two magnets different ways affect how they moved? Why do you think this happened?
2. What conclusions can you make about the different objects tested?
3. Do all objects have this “invisible force” acting on them? If not, which ones?

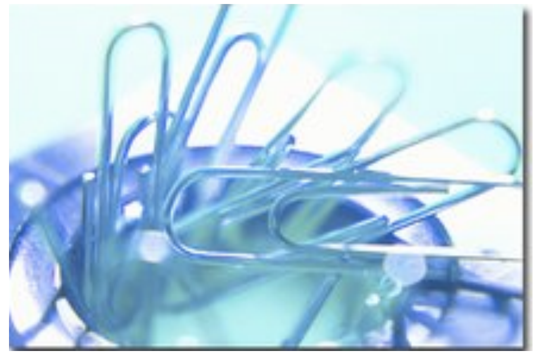
Source

- http://sciencenetlinks.com/lessons/magnets-1-magnetic-pick-ups/

Station 2: Testing the Strength of an Invisible Force

Materials

- Paper clip
- Piece of Thread
- Tape
- Small bar or horseshoe magnet



Procedure

1. Tie one end of the thread to the paper clip.
2. Tape the other end of the thread to the table.
3. Hold the magnet above the paper clip.
4. Try to hold the paper clip up in the air without letting the paper clip and magnet touch.

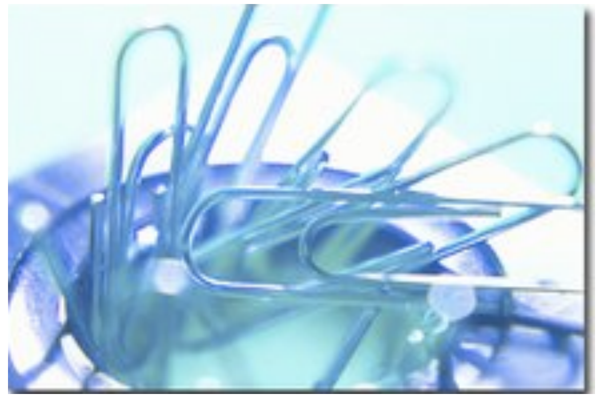
Discussion Questions

1. How do you think the magnet is able to move the paper clip without touching it?
2. Is the magnet always able to move the paper clip?
    a. If not, what factor affects when the magnet can move the paper clip or not?

Source

- http://sciencenetlinks.com/lessons/magnets-2-how-strong-is-your-magnet/

Station 3: Exploring Invisible Fields



Materials

- 2 Bar Magnets
- Paper Clip
- Ziploc bags with 3x5 index card and iron filings inside

Procedure

1. Lay the plastic bag on a table and shake it gently back and forth until there is a thin layer of filings on top of the index card in the bag.
2. Lay the paper clip down at the other end of your desk. Gently life up the bag and hold it right over the paper clip. Record your observations.
3. Lay your magnet at the other end of your desk. Repeat Step 1 and then gently lift up your bag to hold it right over the magnet. Record your observations.
4. Repeat Step 1. Place both magnets end-to-end at the other end of your desk. Gently lift your plastic bag and place it on top of the two magnets. Record your observations.
5. Repeat Step 1. Switch magnets so other ends face each other and place at other end of desk. Gently lift your plastic bag and place it on top of the two magnets. Record your observations.

Discussion Questions

1. The fields we have been exploring are invisible, but the iron filings allow us to see the pattern of the field. How did these filings differ in the different scenarios you conducted above?
2. Where do you see the most filings? This is where the field is the strongest.

Source

- http://sciencenetlinks.com/lessons/exploring-magnetic-fields/

Station 4: Creating Invisible Fields

Materials

- 5 feet insulated copper wire
- 6-volt battery
- D-size battery
- Large iron nail
- Paper clips

Procedure

1. Tightly wrap the wire around the nail, wrapping more than one layer if possible.
2. Try to pick up some paperclips with the wire-wrapped nail. Record your observations.
3. Strip an inch of insulation off each end of the wire (teacher may do this).
4. Hook up the wire to one battery at both ends.
5. Try to pick up the paperclips with the wire-wrapped nail. Record your observations, including how many paperclips you are able to pick up.

Discussion Questions

1. Does the invisible force exist between just the wire-wrapped nail and the paper clips?
2. How were you able to create the invisible force between the wire-wrapped nail and the paper clips?
3. What factors do you think might affect the strength of the invisible force?

Source

- https://www.homesciencetools.com/a/electromagnetism-science-project