Project-Based Inquiry Science: Astronomy
Storyline

Targeted Performance Expectations:
· MS-ESS1-1 · MS-ESS1-2 · MS-ESS1-3 · MS-ESS1-4 · MS-ETS1-3 · MS-ETS1-4

Astronomy: What's the Big Question? How Can You Know If Objects in Space Will Collide?

Storyline (with Disciplinary Core Ideas and Science Content)	Science and Engineering Practices	Crosscutting Concepts
In the Introduction to *Astronomy*, students are introduced to the *Big Question*: *How can you know if objects in space will collide?* After being introduced to the question, students read about one example of a meteorite falling throughout Earth's atmosphere and hitting objects. This story begins the engagement of students into the *Big Question* and is followed by a short video of various collisions. Through each of these examples, students begin to identify evidence of collisions. In small groups, students share what they have seen and begin to identify patterns related to size and mass of objects and the damage they do when they collide. They also begin to consider how knowing the motion of objects in space can help predict collisions and share their current questions and ideas with the class. In the *Tennis Ball Demolition Derby* whole class activity, students make observations, collect data around the predictability of collisions when the path and destination are known compared to when they are unknown and share their results. In this initial activity, students begin to create additional questions about collisions. To complete the *Introduction*, students document their current knowledge (*What do we think we know?*) and investigable questions (*What do we need to investigate?*) that will help them answer the *Big Question*, on the *Project Board.*	**Obtaining, Evaluating, and Communicating Information** (reading about evidence or meteorite collisions and watching a video that describes space object collisions) **Asking Questions and Defining Problems** (asking questions about collisions and evidence of collisions on Earth and other objects, asking questions that are investigable in order to answer the *Big Question* and documenting the questions on the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Astronomy: Learning Set 1 Have Objects in the Solar System Collided?

Storyline (with Disciplinary Core Ideas and Science Content)	Science and Engineering Practices	Crosscutting Concepts
Learning Set 1 Introduction and *Section 1.1*: In the introduction to *Learning Set 1*, students begin identifying, recording, and evaluating evidence of collisions. The starting point is evidence of cratering on the Moon. Using a procedure similar to the scientist Grove Karl Gilbert, students work in small groups and use simple materials to recreate the investigations to gather evidence of the effects of collisions on the moon. This anchoring event, provides students with preliminary data to draw on as they consider the causes and effects of collisions. Dropping various objects into a pan of flour and sand, they "mess about" by varying height, objects, direction and force and record the size and shape of each impact crater as they change the variables. They share their data as a class and craft common understandings about the investigation and the connection and ultimately, through this investigation and discussion, students identify that the size of the object and the mass are critical factors. Using their current understanding of the relationship between mass, size and cratering, students add their claims and evidence to the *Project Board.* They are also encouraged to add additional investigable questions to the *Project Board* at this time.	**Obtaining, Evaluating, and Communicating Information** (observing evidence of cratering on the Moon, introduction to Galileo and other scientists who looked out beyond the Earth to make critical observations) **Developing and Using Models** (physical model of cratering is created and analyzed to identify effect of mass and size of object on crater) **Asking Questions and Defining Problems** (how do mass and size of the object affect cratering on the moon and other solar system objects, additional factors effect the size of craters on the moon, Earth, and other solar system objects)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

<table>
<tr>
<td>Section 1.1 (continued)</td>
<td>Planning and Carrying Out Investigations (develop and implement an experiment to identify the factors that effect crater characteristics)</td>
<td>Section 1.1 (continued)</td>
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<td>Section 1.2:
The students have been provided a list of descriptors for a crater to allow them to talk in their small groups and to label their drawings scientifically. Now, student groups apply the techniques they have developed in the previous activity to planning and conducting an experiment to determine the affect of either mass or size of a dropped object on the size of a crater. They record their ideas for the experiment, share in a Plan Briefing, and update their plan based on the feedback.
Students then run their experiment and carefully record their data. They then use a graph or other tool to analyze the collected data. As they analyze the data, they consider how to describe the effect of the factor they have been assigned (mass or size) and the other variables they have found important.
They then share their results in a Communication Expo, making a poster and presenting it the the rest of the class. Because the groups have investigated two variables, students need the information shared by the other groups to better identify the relationships among the variables. Using directions for presenting and receiving information, students present their results and conclusions and summarize their current knowledge about the ways that cratering can be used as evidence of impacts.
As they reflect on the experiment and their results, students are record summaries of all the experiments and are introduced to the idea that collisions have happened on other solar system objects and that the evidence of this is cratering.</td>
<td rowspan="2">Engaging in Argument from Evidence (multiple opportunities to share developing ideas with others and to support ideas with evidence from investigations and reading, listening to others' claims and including those claims in current thinking)

Analyzing and Interpreting Data (groups analyze and interpret the data collected in their cratering experiences to understand cratering and to identify variables that effect craters)

Obtaining, Evaluating, and Communicating Information (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations)

Constructing Explanations and Designing Solutions (initial development of evidence based claims sare added to the Project Board)

Using Mathematics, Information and Computer Technology, and Computational Thinking (students use mathematics to represent data from their cratering experiments and sharing these ideas with others)</td>
<td>Unit Level:
Systems and System Models
Patterns
Cause and Effect</td>
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<td>Section 1.3:
Craters on the moon are much larger than the craters students have made with their objects however the results of collisions are consistent. Using several photographs of craters on the moon, students identify the size of some moon craters and compare these sizes to distances on Earth. They also compare the characteristics of the craters they have made to the photographs of moon craters and identify the parts of craters on the moon. Students focus on mass and size of objects involved in collisions and identify that on the moon these collisions have created very large craters, therefore the objects must have been very large.
Students read a summary of the moon cratering ideas and make additional connections to their experiments.</td>
<td>Unit Level:
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Section 1.4: Students use what they have observed from moon craters and from their experiments about visible characteristics of craters to search for craters on Earth using Earth imaging software. They begin at the Barringer Crater and find characteristics of craters that match those they have already investigated, identifying characteristics from the satellite images. Students also read about the history of the Barringer Crater, beginning to identify the ages of craters on Earth. Then individual students are provided the name of one of 25 craters on Earth and they search for this crater's location and for characteristics of the crater. They search the Internet for additional information and include all this on a summary card that they use to present their information to the rest of the class. In their presentations, students share the differences between what they have seen in the craters on Earth and those on the moon. Students are introduced to Eugene Shoemaker, a famous American geologist who's work was ignited by a visit to the Barringer Crater. To complete the section, students add their current claims and evidence about cratering on the moon and Earth to the *Project Board*. **Disciplinary Core Ideas:** **ESS1.C: The History of Planet Earth** · The geologic time scale interpreted from rock strata provides a way to organize Earth's history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)	**Asking Questions and Defining Problems** (how do mass and size of the object affect cratering on the moon and other solar system objects, additional factors effect the size of craters on the moon, Earth, and other solar system objects) **Engaging in Argument from Evidence** (multiple opportunities to share developing ideas with others and to support ideas with evidence from investigations and reading, listening to others' claims and including those claims in current thinking) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text about one of 25 Earth craters, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (initial development of evidence based claims about cratering on the moon and Earth are added to the *Project Board*, including information about mass and size of objects as well as comparisons between the Moon and Earth) **Using Mathematics, Information and Computer Technology, and Computational Thinking** (satellite images and imaging software is used to identify 25 craters on Earth and document the characteristics they see)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

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<td>Section 1.5:
Students have begun the discussion of the differences between moon and Earth craters. In this section, they dig deeper into the reasons why by observing several pictures of craters and by reading about the Chicxulub Crater in Mexico. This crater was caused by an impact 65 million years ago but was only identified in the 1970s. Students read that the Earth craters, unlike the moon, are affected by erosion and weathering at various time scales.
They use this information to write an explanation to answer the question Why are craters more difficult to find on Earth than on the moon? Students use multiple evidence sources, including their own experiments and the readings, to support their claims. All students use a common format for their explanation and then are able to share their scientific explanation with each other to make thinking public and prepare to answer the summary questions.

Disciplinary Core Ideas:
ESS1.C: The History of Planet Earth
· The geologic time scale interpreted from rock strata provides a way to organize Earth’s history. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale. (MS-ESS1-4)</td>
<td rowspan="2">Asking Questions and Defining Problems (students dig deeper into understanding why there are differences in cratering on Moon and Earth)

Engaging in Argument from Evidence (multiple opportunities to share developing ideas with others and to support ideas with evidence from investigations and reading, listening to others’ claims and including those claims in current thinking)

Analyzing and Interpreting Data (groups analyze and interpret the data collected in their cratering experiences to understand cratering and to identify variables that effect craters)

Obtaining, Evaluating, and Communicating Information (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations)

Constructing Explanations and Designing Solutions (initial development of evidence based claims related to cratering on Earth compared to the Moon are added to the Project Board)</td>
<td>Unit Level:
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<td>Section 1.6:
As much as is practical, students have investigated how craters occur and the variables of the collision objects that create different craters. Now they read about the process of collisions between space objects. Through this reading they consolidate their experiences in experimentation and collecting data about Earth craters to better understand the process that happens on Earth, particularly the interaction of the Earth’s atmosphere with objects. Students are also introduced to the idea that gravity is a powerful force in this process.
They complete this section by updating the Project Board, adding information about cratering and meteors. Students make claims and support them with evidence from the anchoring event and from several science readings.</td>
<td>Unit Level:
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Cause and Effect</td>
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Section 1.7: Later in the unit, students will be able to identify various solar system objects as well as some objects outside of the solar system. In this section, they are introduced to the solar system objects and begin to use Internet research to read more about one object they are assigned. Through this reading they are introduced to the work of astronomers from the distant and recent past, including Edmund Halley and Carolyn Shoemaker. Students then watch a video of the Comet Shomaker-Levy 9 as it collides with Jupiter in 1994. Students read about the differences between Jupiter and Earth and begin to identify the results that might occur as collisions happen with other solar system bodies. Students have now read about Eugene Shoemaker and Carolyn Shoemaker at several places in the *Learning Set* and have identified a variety of ways their work has been critical to answering the *Big Question*. In summarizing the reading, students look back to *Section 1.2* and revise their answer to the question about cratering on other planets, using the information from the current reading. Students update the *Project Board*, adding their current claims about cratering on Earth and other solar system objects as well as evidence from their reading. **Disciplinary Core Ideas:** **ESS1.A: The Universe and Its Stars** · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3)	**Asking Questions and Defining Problems** (students ask questions about assigned solar system objects and the effects of collisions between objects) **Engaging in Argument from Evidence** (multiple opportunities to share developing ideas with others and to support ideas with evidence from investigations and reading, listening to others' claims and including those claims in current thinking) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (claims and evidence related to additional solar system objects and collisions are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Back to the *Big Question*: Students now apply what they have learned about size, mass, atmosphere, cratering and other concepts to predicting the effect of a collision between Earth and one of four objects (Halley's comet, a meteor identified in 1972, Asteroid 1999 AN10, and Asteroid 433 Eros). In small groups, they research their assigned object and use these characteristics to make a claim about the potential collision. They prepare a summary poster and share with the class in an *Investigation Expo*. They also reflect on their learning and begin to organize their research on various solar system objects using evidence of past collisions, chance of future collisions, and what would happen in a collision, as three of the organizing categories. Students complete this section but writing or updating their explanation answering the *Big Question*: How can you know if objects in space will collide? They also share their current explanation and, using the ideas of others, update their explanation. Ideas from the explanations are added to the *Project Board*, to make visible the current thinking of all students. **Disciplinary Core Ideas:** **ETS1.B: Developing Possible Solutions** · A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) · Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) · Models of all kinds are important for testing solutions. (MS-ETS1-4)	**Asking Questions and Defining Problems** (students use characteristics of one of four solar system) **Planning and Carrying Out Investigations** (develop and implement an experiment to identify the factors that effect crater characteristics) **Engaging in Argument from Evidence** (multiple opportunities to share developing ideas with others and to support ideas with evidence from investigations and reading, listening to others' claims and including those claims in current thinking) **Analyzing and Interpreting Data** (groups analyze and interpret the data collected in their cratering experiences to understand cratering, to identify variables that effect craters and apply that information to one of four new objects) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text regarding one of the four solar system objects, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (students update the *Project Board* to document anything missing from the Learning Set and add evidence to support previous claim, as appropriate)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Astronomy: Learning Set 2 How do Earth, the Moon, and the Sun Move Through Space?		
Storyline (with Disciplinary Core Ideas and Science Content)	**Science and Engineering Practices**	**Crosscutting Concepts**
Introduction to *Learning Set 2*: In *Learning Set 2,* students begin to investigate patterns in motion, the predictability of motion of solar system objects, and the causes of this predictability. They start with those solar system objects that are closest to Earth as they investigate the interactions among the Sun, Moon and Earth that cause phases of the moon and eclipses. These introductory modeling experiences lay the foundation for observing the motion of additional planets later in the *Learning Set* and predicting how changes, caused by or causing, collisions, might occur.	**Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions (**iterative development of evidence based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

<table>
<tr>
<td>Section 2.1:
As students begin to think about the motion of solar system bodies, the first consider the rotation of Earth through a story about Foucalt's Pendulum. They investigate changes in the orientation of the shadow created by a sundial throughout a day. This evidence supports initial explanations that the Sun or the Earth must be rotating.
Students obtain additional information about how sundials work and apply that to their explanations about the apparent motion of the Sun. Using this information, students update the Project Board, including initial explanations as well as questions they might want to investigate that have been uncovered through the investigation.</td>
<td rowspan="3">Developing and Using Models (physical model of the Sun, Earth, Moon system is created and analyzed to identify effect of the ordering of the objects on phases of the moon and eclipses. Model used to identify and predict orbits and predictability)

Asking Questions and Defining Problems (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created)

Planning and Carrying Out Investigations (develop investigations with models to identify phases of the moon, sizes of planets, and eclipses)

Engaging in Argument from Evidence (creating arguments about the origins of the moon based on current collision theory)

Analyzing and Interpreting Data (collected sketches act as data for phases of moon and eclipses)

Obtaining, Evaluating, and Communicating Information (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations)

Constructing Explanations and Designing Solutions (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the Project Board)

Using Mathematics, Information and Computer Technology, and Computational Thinking (students use mathematics to represent identify scale and proportion in their Sun, Moon, Earth models)</td>
<td>Unit Level:
Systems and System Models
Patterns
Cause and Effect</td>
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<td>Section 2.2:
Using a globe, student groups begin to investigate their initial ideas about the relationship between motion of Earth and the apparent motion of the Sun. Using a flashlight, students observe changes in the direction, length and direction and length of a shadow created by a pencil held perpendicular to the globe. Students document the changes in sketches and use scaffolded questions support students as they analyze the data to recognize that the Earth must rotate and revolve in order to create changes in length and distance.
Using their investigation results and a reading, students explain what movements of Earth are supported by the current evidence and show that the Earth must be in motion.
Students share their explanation with other groups and update them given ideas and evidence they have received from others. These ideas are then added to the Project Board.

ESS1.B: Earth and the Solar System
· [The] model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)</td>
<td>Unit Level:
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Cause and Effect</td>
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<tr>
<td>Section 2.3:
Applying their understanding that movement of Earth causes the apparent motion of the Sun, students now begin to investigate the motion of the moon.First they use a graphic representation of the motion of the moon to investigate how the motion changes over the course of a day. In analyzing this data, student groups describe the motion and compare the apparent motion of the Sun to the motion of the moon. They complete a set of questions that help them begin to consider how the motion of the Moon might cause the phases of the moon.
In Investigation 2, students observe changes in the appearance of the moon over a two week time period using a graphic representation. Again, they analyze the data and use the model to make predictions about how the appearance of the moon changes over time.
As they reflect on the two investigations, students compare the graphics for changes in the motion of the moon and its appearance, considering trends observed in the two graphics.

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

Section 2.3 (continued): Now students use their developing understanding of the phases of the moon to create a simple model, using sticks and balls to represent Earth, Sun and Moon. In this third investigation, students use a light source to represent the Sun and move Earth and the moon to simulate the phases of the moon they had been introduced to in the previous investigation. In the fourth investigation, students model the motions of the Moon and Earth in this system. After they have modeled the Moon's motion, they simulate the motion of a different satellite that revolves more quickly. Students begin to see how the mo-tion of the solar system bodies affect how they are seen. Students share their models with the whole class and discuss how the models are the same and different, looking for trends across the groups. They discuss the order of the phases and the direction of motion of orbiting planet that causes the phases. Finally, they use the model to demonstrate that the moon phases are created because of the interactions between the three solar system objects. As they reflect on the four investigations, students predict how the interactions among the three solar system objects would be changed if the order or motion of the objects changed, providing more evidence that the Sun is stationary and the Earth and Moon are both in motion. To complete the section, students read about moon phases and compare a graphic representation of the phases of the Moon to their models. Students then synthesize their ideas and write a scientific explanation for the phases of the moon. This explanation is shared with the class and revised. Using the information from the explanations, students engage in a discussion to add their ideas to the *Project Board.* **Disciplinary Core Ideas:** **ESS1.A: The Universe and Its Stars** · Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1) · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3)	**Developing and Using Models** (physical model of the Sun, Earth, Moon system is created and analyzed to identify effect of the ordering of the objects on phases of the moon and eclipses. Model used to identify and predict orbits and predictability) **Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created) **Planning and Carrying Out Investigations** (develop investigations with models to identify phases of the Moon, sizes of planets, and eclipses) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions (**iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*) **Using Mathematics, Information and Computer Technology, and Computational Thinking** (students use mathematics to represent identify scale and proportion in their Sun, Moon, Earth models)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Section 2.4: To answer the *Big Question* it is important for students to better understand the scale of solar system objects. Students frequently have difficulty visualizing and interpreting scale in size and distance of solar system objects. In this section, students begin exploring these large sizes and distances by investigating models of the Sun, Moon and Earth that help in describing the scale of the objects compared with each other. Students have multiple experiences observing the size of the Moon so they are asked to make a prediction about the comparison between the size of the Earth and Moon. They then use clay to build two clay spheres that are in proper scale to each other 49:1 to represent the Earth and the Moon. Using ratios, students compare the actual scale sizes of Earth and the Moon with their prediction. They then use the scale model of the solar system objects to predict the distances between Earth and the Moon. By measuring the diameter of Earth, they learn the scale distance (accurate to the scale of their current model) between the two objects. Because each group began with a different amount of clay, groups Earth and Moon models will vary in size and the distances between them will also vary. In this way, students' developing understanding of scale will be reinforced. As an introduction to investigations later in the unit, students read about the celestial sphere and measurement of celestial objects from Earth. **ESS1.B: Earth and the Solar System** · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3) · This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)	**Developing and Using Models** (physical model of the Sun, Earth, Moon system is created and analyzed to identify effect of the ordering of the objects on phases of the moon and eclipses. Model used to identify and predict orbits and predictability) **Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created) **Planning and Carrying Out Investigations** (develop investigations with models to identify phases of the Moon, sizes of planets, and eclipses) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions (**iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*) **Using Mathematics, Information and Computer Technology, and Computational Thinking** (students use mathematics to represent identify scale and proportion in their Sun, Moon, Earth models)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Section 2.5: Students have used a model to explain the phases of the moon and to begin to use the motion of the Earth and Moon to describe and predict the affect of the interactions between the to objects. In this Section, students use the same model materials to identify the positions of the Sun, Moon and Earth when a solar and lunar eclipses occurs. After sketching their model, students evaluate their models and compare eclipses to the phases of the moon through a series of discussion questions. Building on the developing understanding of the interactions between solar system bodies, students read about gravitational force between Earth and the Moon that causes tides. **Disciplinary Core Ideas:** **ESS1.A: The Universe and Its Stars** · Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1) · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3) **ESS1.B: Earth and the Solar System** · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3) · This model of the solar system can explain eclipses of the sun and the moon. Earth's spin axis is fixed in direction over the short-term but tilted relative to its orbit around the sun. The seasons are a result of that tilt and are caused by the differential intensity of sunlight on different areas of Earth across the year. (MS-ESS1-1)	**Developing and Using Models** (physical model of the Sun, Earth, Moon system is created and analyzed to identify effect of the ordering of the objects on phases of the moon and eclipses. Model used to identify and predict orbits and predictability) **Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created) **Planning and Carrying Out Investigations** (develop investigations with models to identify phases of the moon, sizes of planets, and eclipses) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions (**iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*) **Using Mathematics, Information and Computer Technology, and Computational Thinking** (students use mathematics to represent identify scale and proportion in their Sun, Moon, Earth models)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Back to the Big Question: Students now apply several explanatory statements: the Moon and Earth obit in predictable, non-intersecting paths, and along with the Sun, create moon phases and eclipses when oriented in predictable ways. Using what they know, students obtain information about the formation of the Moon and consider this animation and evidence that supports the theory that the Moon was created through a collision of another body and Earth. Students evaluate this theory, consider evidence that would support the theory, and share their ideas with others. They then update their scientific explanation about collisions, focusing on the evidence about predictability and past collisions. After sharing and revising their current explanations, the class adds their information to the *Project Board*. **Disciplinary Core Ideas:** **ETS1.B: Developing Possible Solutions** · A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) · Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) · Models of all kinds are important for testing solutions. (MS-ETS1-4)	**Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Astronomy: Learning Set 3
How Do Other Solar-System Objects Move Through Space?

<table>
<tr><th>Storyline (with Disciplinary Core Ideas and Science Content)</th><th>Science and Engineering Practices</th><th>Crosscutting Concepts</th></tr>
<tr><td>Learning Set 3 Introduction:
Students now extend their explanations regarding collisions to solar-system objects that are beyond the Sun, Moon, Earth interaction to solar system objects that extend out to the edges of the solar system.</td><td rowspan="4">Developing and Using Models (of the solar system is created and analyzed to identify identify and predict orbits)

Asking Questions and Defining Problems (ask questions about solar system objects, size, scale and motion)

Engaging in Argument from Evidence (creating arguments about the possibility that objects in the solar system can collide)

Obtaining, Evaluating, and Communicating Information (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations)

Constructing Explanations and Designing Solutions (iterative development of evidence-based claims and explanations regarding collisions of space objects. Claims focus on potential of collisions. Claims and evidence are added to the Project Board)</td><td>Unit Level:
Systems and System Models
Patterns
Cause and Effect</td></tr>
<tr><td>Section 3.1:
Students investigate size, scale and predictability of orbit as they obtain information about a solar system object, communicate that information to other groups, and continue to update their explanations about collisions. They add information about the solar-system objects to the Project Board to publicly record trends in solar-system objects.

Disciplinary Core Ideas:
ESS1.B: Earth and the Solar System
· The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)</td><td>Unit Level:
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<tr><td>Section 3.2:
In preparation for the solar system model walk and to better visualize the size and scale of the solar system, students determine a scale factor (mathematically) and use that factor to determine the scale sizes of the solar-system objects they researched in Section 3.1. Again, students pause to add their current understanding of scale to the Project Board.</td><td>Unit Level:
Systems and System Models
Patterns
Cause and Effect</td></tr>
<tr><td>Section 3.3:
Using the scale model created in the previous work, students now consider the predictability of motion as part of the model. They look for patterns of planetary motion through a simulation. Additional reading introduces gravity as the force that creates the orbits and maintains the planets in these predictable orbits. They then apply the understanding of motion to defining year and compare the year of different planets. They also use the model to make predictions about the effects to the orbits of planets if the planets' distance from the Sun changed and predictions about the likelihood of planetary collisions. This information is then added to the Project Board.

Disciplinary Core Ideas:
ESS1.A: The Universe and Its Stars
· Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)
· The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MSESS1-3)
ESS1.B: Earth and the Solar System
· The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)</td><td>Unit Level:
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Section 3.4: Since people have, up until recently, been grounded on Earth to observe the motion of planets, students now imagine how the motion they simulated would look from Earth. They use a simulation to predict and describe the motion of the planets compared to the background of stars, the "celestial sphere" they explored previously. They analyze the data from the simulation looking for trends and patterns of motion among the planets and against the background of the constellations. To build on the nature of science focus of the unit, Students read about how others have used their observations to define and then redefine the motion of the solar system (Copernicus, Galileo and Kepler). **Disciplinary Core Ideas:** **ESS1.B: Earth and the Solar System** · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)	**Developing and Using Models** (of the solar system is created and analyzed to identify identify and predict orbits) **Asking Questions and Defining Problems** (ask questions about solar system objects, size, scale and motion) **Engaging in Argument from Evidence** (creating arguments about the possibility that objects in the solar system can collide) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations regarding collisions of space objects. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**
Section 3.5: Students have modeled and researched large solar system bodies and their predictable orbits. They now read about how the solar system was created (current theory) and identify the small asteroids that exist in the solar system. These Near Earth Objects can cross the orbit of Earth and students use the information from the reading to make a prediction of the possibility that these objects would cause collisions with Earth. They then add their claims and evidence to the *Project Board.* **Disciplinary Core Ideas:** **ESS1.B: Earth and the Solar System** · The solar system appears to have formed from a disk of dust and gas, drawn together by gravity. (MS-ESS1-2)		Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**
Back to the Big Question: Students now return to the *Big Question* to identify and make connections to their knowledge of solar system objects and potential for collisions. They obtain additional information bout near earth objects and evaluate data relative to the possibilities of collisions. They share their predictions with the class and then update their current explanations in their small groups. As a group, they update their explanations and then add the information to the *Project Board.* **Disciplinary Core Ideas:** **ETS1.B: Developing Possible Solutions** · A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) · Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) · Models of all kinds are important for testing solutions. (MS-ETS1-4)	**Asking Questions and Defining Problems** (ask questions about solar system objects, size, scale and motion) **Engaging in Argument from Evidence** (creating arguments about the possibility that objects in the solar system can collide) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations regarding collisions of space objects. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Astronomy: Learning Set 4
How Do Objects Outside Our Solar System Move Through Space?

Storyline (with Disciplinary Core Ideas and Science Content)	Science and Engineering Practices	Crosscutting Concepts
Introduction to *Learning Set 4* and *Section 4.1*: Moving out past the solar system and including additional opportunities to engage in exploring the nature and history of science, students focus on applying what they have noticed about patterns of motion in the solar system. Using images students consider what claims can be made based on the amount of light that is observed as emitted by an object. They make predictions about the relationship between brightness of light and the distance an object is from the observer. Students make tentative claims and add these to the *Project Board*. *Section 4.2:* Students use their eyes to explore how light might be observed with other tools of astronomy. They make connections between light and distance and then move beyond this relationship to explore more about the distances to objects outside of the solar system. Students explore parallax with their eyes and makes sketches and models that help them explain parallax. They then connect their experiences with parallax to the measuring challenges of identifying the position and distance of far away objects.	**Developing and Using Models** (physical model of the Sun, Earth, Moon system is created and analyzed to identify effect of the ordering of the objects on phases of the moon and eclipses. Model used to identify and predict orbits and predictability) **Asking Questions and Defining Problems** (ask questions about eclipses and phases of the moon, predictability of planet motion, size and ordering of solar system objects, how the moon was created)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**
Section 4.3: Building on the introduction to stars provided throughout the rest of the unit, students now obtain and evaluate information about the Milky Way. Using data tables of bright and close stars, students compare the lists and find patterns that indicate a relationship between absolute brightness and distance. Students use their developing ideas regarding distance and brightness to explain these trends. Students read about the number of stars and the structure of the Milky Way. **Disciplinary Core Ideas:** **ESS1.A: The Universe and Its Stars** · Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1) · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)	**Planning and Carrying Out Investigations** (develop investigations with models to identify phases of the moon, sizes of planets, and eclipses) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

<table>
<tr>
<td>Section 4.4:
Students begin to recognize that collisions have happened on different time scales, 100s of billions of years ago as well as today, collisions occurring in the universe. They apply this information to model the frequency of collisions in the early galaxy formation and to help explain why the galaxy has a spiral shape.
Students obtain information about how astronomers measure characteristics of stars and apply their understanding of the Doppler Shift to changes in sound. They use this experience with sound to better explain the blue and red shifts and the information these shifts provide astronomers about starts that are very far from earth. Students then evaluate and predict how the position within the Milky Way would change the solar system and compare the structure and motion of the solar system and the Milky Way.

Disciplinary Core Ideas:
ESS1.A: The Universe and Its Stars
· Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1)
· The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)</td>
<td rowspan="2">Planning and Carrying Out Investigations (develop investigations with models to identify phases of the moon, sizes of planets, and eclipses)

Engaging in Argument from Evidence (creating arguments about the origins of the moon based on current collision theory)

Analyzing and Interpreting Data (collected sketches act as data for phases of moon and eclipses)

Obtaining, Evaluating, and Communicating Information (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations)

Constructing Explanations and Designing Solutions (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the Project Board)</td>
<td>Unit Level:
Systems and System Models
Patterns
Cause and Effect</td>
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<tr>
<td>Section 4.5:
Students obtain information from the text about how images and light have provided data to support the classification of stars. They read about Annie Jump Cannon's work in the 1890s and Hertzsprung and Russel in the early 1900s. Students envision how changes to the ways of classifying stars have occurred over time depending on the availability of observational data. Then students read about three different types of stars - Giants, Supergiants, and White Dwarf and compare the characteristics of these stars to the Sun. They make connections between the type of stars and the life of a star.
Students read more about types of stars and common data collection mechanisms of today in a section on radio astronomy. They complete this section by reading about Nobel Prize winner Chandrasekhar who is an expert on the structure of stars.

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

Section 4.6: Moving beyond the Milky Way galaxy, students begin to consider other galaxies and the scientists and scientific tools used to look deep into space to observe the characteristics and motion of other galaxies. Building on their developing understanding of the timeline of astronomy, students now explore the potential for galaxies to collide by learning about Harlow Shapley and Heber Curtis' debate over galaxies. They also read about Henriette Swan Leavitte and Edwin Hubble. Using images, students compare the shapes of four galaxies and then use these characteristics to classify the galaxies. They then share their classification systems and apply their system to another galaxy. With this knowledge of galaxies, students read about collisions between galaxies that have occurred and continue to be observed even though they happened far away and far in the past. Students read that many of these collisions are predictable based on the motion of galaxies and that these collisions will not affect Earth. In updating the *Project Board*, students evaluate the information in light of the *Big Question* and add the information to the board. **Disciplinary Core Ideas:** **ESS1.A: The Universe and Its Stars** · Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. (MS-ESS1-1) · The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. (MS-ESS1-2),(MS-ESS1-3)	**Planning and Carrying Out Investigations** (develop investigations with models to identify phases of the moon, sizes of planets, and eclipses) **Engaging in Argument from Evidence** (creating arguments about the origins of the moon based on current collision theory) **Analyzing and Interpreting Data** (collected sketches act as data for phases of moon and eclipses) **Obtaining, Evaluating, and Communicating Information** (several opportunities for reading scientific text, evaluating it in light of the investigations, and communicating ideas with others by incorporating the ideas into scientific explanations and presentations) **Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**
Section 4.7: To complete the *Learning Set,* students explore two case studies of the current powerful tools of astronomy: Hubble Space Telescope and the Kepler Mission. Both of these tools have allowed us to detect objects in ways that we had not done before and to collect data that was not available by other means. Through reading and video, they obtain information about each mission and explore the information that the missions have provided people about the universe. In a conference, students evaluate and potentially argue about the need for these missions and the mission goals. They then use this information to create and discuss their own ideas of a critically needed space mission.		

Back to the Big Question: Students update their explanations based on their growing knowledge of galaxies and solar systems. They then share these updated explanations and add their new claims and evidence to the *Project Board*. **Disciplinary Core Ideas:** **ETS1.B: Developing Possible Solutions** · A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) · Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) · Models of all kinds are important for testing solutions. (MS-ETS1-4)	**Constructing Explanations and Designing Solutions** (iterative development of evidence-based claims and explanations are embedded within materials. Claims focus on potential of collisions. Claims and evidence are added to the *Project Board*)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**

Astronomy: Answer the Big Question
How Can You Know If Objects in Space Will Collide?

Storyline	Science and Engineering Practices	Crosscutting Concepts
To conclude the Unit, students make their final explanations. To do this, they research and then write a three part report in which they choose a collision and use it to explain in what ways people can know of objects in space will collide. They revise their explanations based on several criteria that they have investigated throughout the unit. **Disciplinary Core Ideas:** **ETS1.B: Developing Possible Solutions** · A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (MS-ETS1-4) · Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (MS-ETS1-3) · Models of all kinds are important for testing solutions. (MS-ETS1-4)	**Asking Questions and Defining Problems** (ask questions about predictably and potential of collisions in space) **Engaging in Argument from Evidence** (creating arguments based on evidence for the potential for collisions in space) **Obtaining, Evaluating, and Communicating Information** (sharing of ideas related to evidence of collisions, updating explanations based on evidence) **Constructing Explanations and Designing Solutions** (conclusion of explanation regarding collisions in space are created and supported by evidence from the unit)	Unit Level: **Systems and System Models** **Patterns** **Cause and Effect**