UNIT STORYLINE

How students will engage with each of the phenomena

HANDS-ON/ LAB ACTIVITIES | VIDEOS OR IMAGES | DATA SETS | READINGS | COMPUTER INTERACTIVES

Unit Question: How are we connected to the patterns we see in the sky and space?

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>

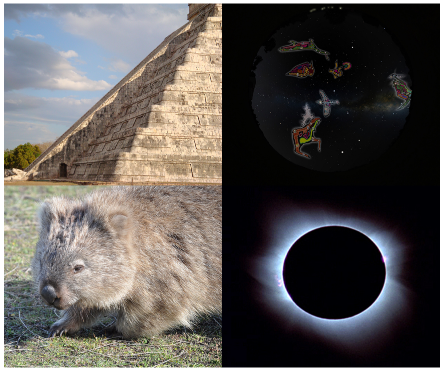
LESSON 1

4 days

How are we connected to the patterns we see in the sky?

Anchoring Phenomenon

</td>
<td>



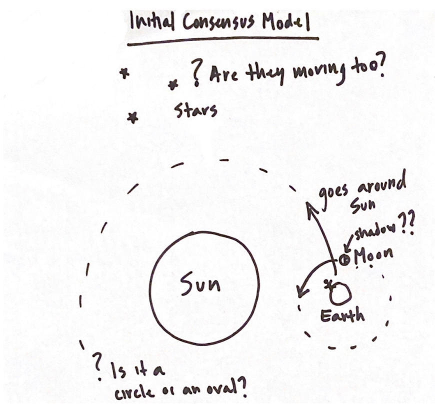
The sun sets between buildings in New York City just two days of the year. People across cultures and time have studied the sky and relied on connections to the sky in their lives.

</td>
<td>

We analyze and consider how light from the Sun aligned with structures made by humans on a particular day and develop an initial model to explain this phenomenon. We gather, connect with, and jigsaw stories about patterns in the sky they have seen or heard about and how these might be connected to the rhythms of human life. We develop a model of the parts of the system that are needed to explain many of the patterns we have identified. We figure out:

- Changing patterns in the sky connect to our lives and set rhythms for life on Earth.
- Stories and analogies related to the sky are legitimate ways to preserve knowledge about the stars and planets and aid in observing and decision making.
- We observe the light coming from distant objects in the sky.
- Light travels in a straight line; it must enter our eye in order for us to see the object it came from.
- The Earth spins around, or rotates, on its axis once every day and goes around or orbits the Sun once every year.
- In order to better explain and understand a complex system, we may need to view/visualize it from multiple perspectives.

</td>
<td>



</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** We want to collect more of our own observations of the sky and hear more stories about communities that paid close attention to the sky to see how it shaped their lives.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>

LESSON 2

1 day

What patterns are happening in the sky that I have experienced and can observe (through models and tools)?

Investigation

</td>
<td>

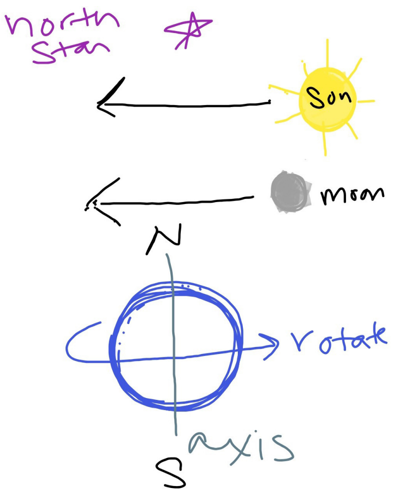
There are repeating patterns in the paths that the Sun and stars appear to move through the sky over time.

</td>
<td>

We gather information from videos of Native American stories about a star that does not move in the night sky. We share our experiences about noticing this star, sometimes called the North Star. We watch a video and share the repeated patterns and changes that we observe in the sky. We develop initial models to explain why the North Star does not appear to move in the night sky. We figure out:

In the Northern Hemisphere, the Earth's axis is always pointed toward the North Star, which explains why it does not appear to move in the night sky.
The Sun and Moon always appear to rise in the eastern sky, move across the sky from east to west, and set in the west.
The stars visible in the night sky in the Northern Hemisphere appear to move counterclockwise in a circular path around the North Star. This is because the Earth spins counterclockwise on its axis when looking down on it from above its North Pole.

</td>
<td>



</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** Though we noticed some important patterns of change in the Sun over time, there is something else that remains constant (the Earth's north is always tilted to point toward the North Star). We think there are some possible advantages in trying to develop a model of this system using physical manipulatives to help explain these differences.

<table>
<tr>
<td>

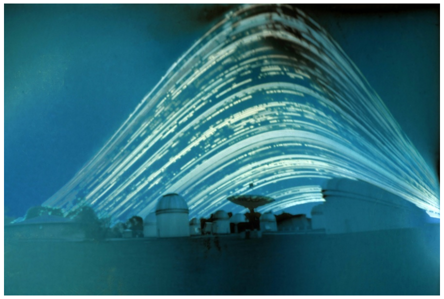
LESSON 3

3 days

How can we explain the Sun's path change over time?

Investigation

</td>
<td>



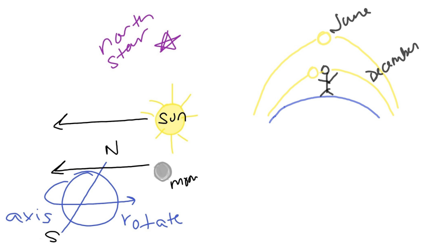
Patterns of the Sun in the sky and sunlight over the globe vary in predictable patterns every year.

</td>
<td>

We watch a video to observe the simulated motion of the Sun through the sky over a day for different times of the year. We notice that in summer the apparent path of the Sun in the sky is higher and the daytime is longer. We create physical models to see if our understanding about why this is happening is correct. Our physical models cannot account for differences in the length of daylight over a year. We revise our model of the system in small groups to try to account for changes in the amount of daylight. We figure out:

Changes in the length of a day and angle of elevation of the Sun in the sky occur in a regular, repetitive, and cyclical pattern.
Earth's axis is tilted at an angle and is pointed in the Northern Hemisphere towards Polaris, also called the North Star.
As the Earth orbits around the Sun and is tilted on its axis, we observe changes in the amount of daylight and how high the Sun is in the sky over the course of the year.

</td>
<td>



</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** Though we think that what we figured out about what causes the intensity of sunlight on Earth's surface and Sun's elevation in the sky to change over time, we wonder if this could also help explain other seasonal patterns like the change in temperature over the course of a year.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>

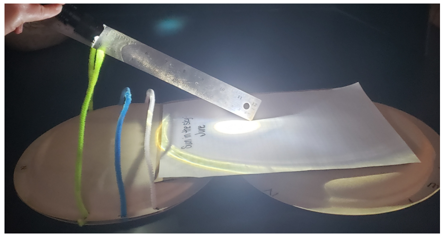
LESSON 4

2 days

How do these changes in sunlight impact us here on Earth?

Investigation

</td>
<td>



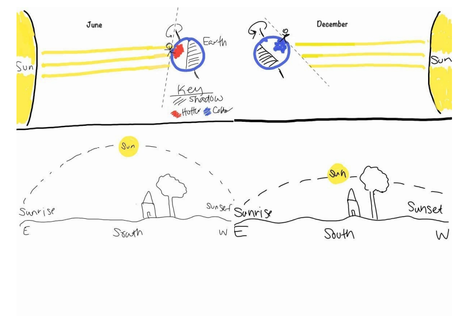
When a flashlight shines on graph paper, at different angles, it produces a different sized spot on the paper.

</td>
<td>

We analyze seasonal temperature data from two cities in the US and argue that changes in Earth's distance from the Sun do not explain seasonal temperature differences. We develop a physical model and use it to collect changes of sunlight energy on Earth's surface as a result of changes in solar elevation. We use this relationship to explain seasonal temperature differences in other parts of the world. We figure out:

- Solar elevation causes differences in the intensity of light reaching Earth's surface throughout the year.
- Higher solar elevation results in more direct sunlight and greater light energy reaching Earth's surface, causing higher temperatures.
- Lower solar elevation results in sunlight being more spread out and less light energy reaching Earth's surface, causing lower temperatures.
- When sunlight is more direct in the Northern Hemisphere, it is at an angle in the Southern Hemisphere, and vice versa.

</td>
<td>



</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** We can use our new understanding about Earth's tilt and solar elevation to revise our models and better explain Manhattanhenge and other related seasonal phenomena.

<table>
<tr>
<td>

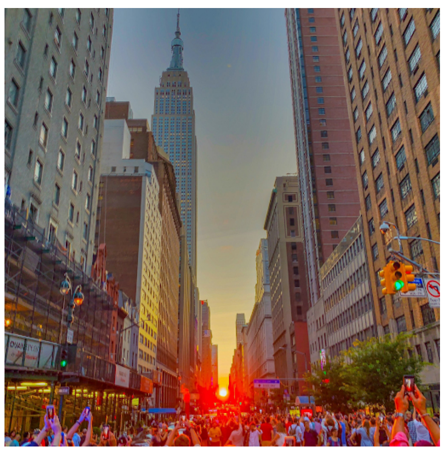
LESSON 5

1 day

How can we explain phenomena like Manhattanhenge?

Putting Pieces Together, Problematizing

</td>
<td>



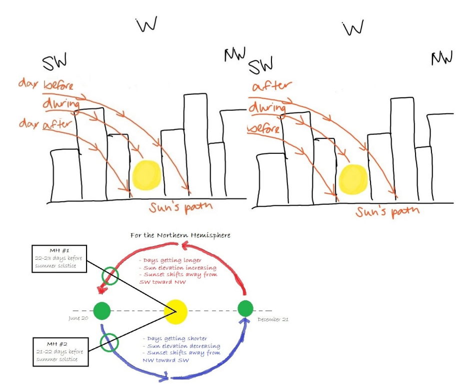
The sun sets between buildings in New York City just two days of the year.

</td>
<td>

We use a video simulation to investigate patterns we think might be responsible for Manhattanhenge. We revise a model of the Manhattan solar phenomenon. We revisit the Driving Question Board to connect what questions we have answered and what questions remain. We figure out:

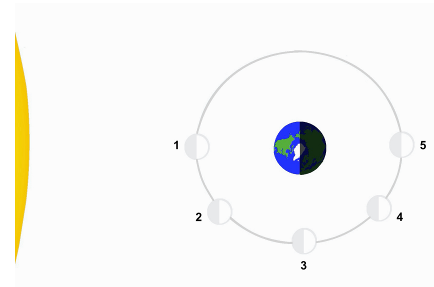
- The light rays from the Sun at sunset follow a straight path that happens to align down many streets between the buildings on either side in Manhattan only 2 times a year.
- There is a reversal (symmetry) in the pattern of change in where the Sun sets (and rises), the day length, and the angle of the Sun in the sky that occur over the year between the summer and winter solstice.
- The fixed tilt of Earth's axis and its orbit around the Sun causes this reversal in these patterns of change between the two extreme points in its orbit, in terms of how much the Earth's tilt is pointed toward the Sun (summer solstice and winter solstice).

</td>
<td>

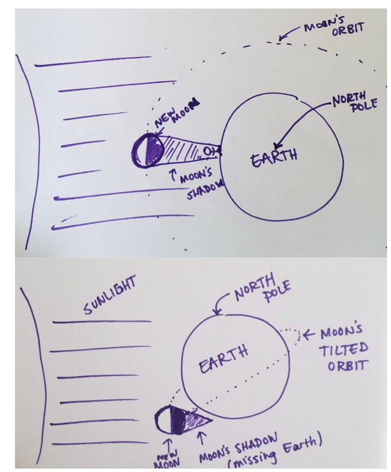


</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** Though we explained a lot about patterns related to the Sun, the Sun wasn't the only thing we were curious about. We also had a lot of questions on the DQB about the Moon. We are wondering how we can add the Moon to our Sun-Earth model to explain some of its patterns.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 6 2 days **Why do we see the shape of the Moon change?** Investigation 	 *The shape of the Moon seen from Earth changes monthly from full circle to nothing.*	We use a physical model and an online interactive to help make sense of the positions of the objects in the Earth-Sun-Moon system that cause us to see the current shape of the Moon. We also use our physical models to predict the next phase of the Moon. We figure out: • People have watched the Moon across time and cultures. • Light from the Sun shines on one side of the Moon at any time. The Moon is always "half-lit." • The shape of the Moon we see from one day to the next is a result of its position in space relative to Earth; the appearance of the shape of the Moon that we see on any particular day can be explained in terms of how much of the sunlit side we can see at that time. • We can see the Moon at different times of the day and night—and sometimes not at all.	

⇓ **Navigation to Next Lesson:** We realized that the Moon can be out during the day and that in certain positions it could affect what we see of the Sun. We now wonder about this phenomenon we think is called an eclipse.

LESSON 7 2 days **Why do we see eclipses and when do we see them?** Investigation 	 *Sometimes the Sun gets blocked by the Moon.*	We watch a video of a solar eclipse. We develop a model to explain what we saw in the video using a physical model of the system. We compile the ideas we want to include in a drawn model using multiple perspectives to communicate what is seen when a solar eclipse happens and why. We return to our physical models to figure out why we do not see a solar eclipse every month and how often we might expect to see a solar eclipse. We figure out the following: • Sometimes the Moon lines up in its orbit between the Sun and the Earth, resulting in the Moon casting a shadow on the Earth. This is what causes a solar eclipse. • The Moon's orbit is not perfectly flat relative to Earth's orbit around the Sun; it is tilted just a little. This is why we don't see eclipses every month.	

⇓ **Navigation to Next Lesson:** We figured out why and when solar eclipses occur and we predicted what we will see when there is a lunar eclipse. We want to get some additional data on lunar eclipses to see if our prediction was correct.

<table>
<tr><th>Lesson Question</th><th>Phenomena or Design Problem</th><th>What we do and figure out</th><th>How we represent it</th></tr>
<tr>
<td>

LESSON 8

1 day

What does a lunar eclipse look like and how can we explain it?

Problematizing

</td>
<td>

The Moon looks reddish during a total lunar eclipse (not dark like we predicted).

</td>
<td>

We analyze images of lunar eclipses and compare them to the lunar eclipse predictive model we made as a class in Lesson 7. The reddish color of the Moon that we observe during a lunar eclipse is unexpected. So we list possible causes of that reddish color and gather examples of related phenomena of objects reddening in the sky. After posting our color-related questions, we generate ideas for investigating them. We figure out:

- The Moon is full during a lunar eclipse; this is what our model predicted.
- The Moon turns reddish and dim (but is still visible) during a lunar eclipse but does not become completely dark (not visible); this is not what our model predicted.
- There are other times when we have experienced the Moon or Sun changing color like this (to reddish or orange).

</td>
<td>

What causes a change in color for the Sun, Moon, or other things?

Ideas for Investigation

- Use flashlights and spheres again
- Use simulations
- Analyze photos of these objects and when these color changes occur
- Shine lights on or through various things to look for color change

</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** The color change of the Moon in a lunar eclipse (and its dimming rather than completely darkening) was not predicted by our model. So, we plan to explore related phenomena (color and brightness changes of the Sun and Moon at other times) to help us figure out what is happening in the system during a lunar eclipse and help us make progress on other color-related questions.

<table>
<tr>
<td>

LESSON 9

1 day

Why do the Moon and Sun appear to change color near the horizon?

Investigation

</td>
<td>

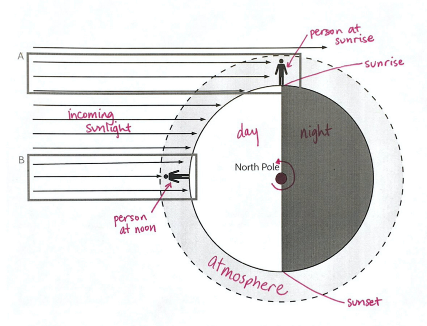
The Sun and Moon turn a reddish color when they're rising or setting. Earth is surrounded by an atmosphere that forms a curved layer of gas, water droplets, ice crystals, and dust particles surrounding the entire surface of the Earth, about 60 miles thick, which gets less dense the further up you go.

</td>
<td>

We examine images of the Sun and Moon and propose that something about the Earth's atmosphere could be contributing to the color changes. We examine diagrams of the atmosphere and images of the Sun from space. We add the Earth's atmosphere to our model of the Earth–Sun system and zoom in on the Sun at different times. We predict different angles of light and/or the amount of the atmosphere affects the color at sunrise compared to midday. We figure out:

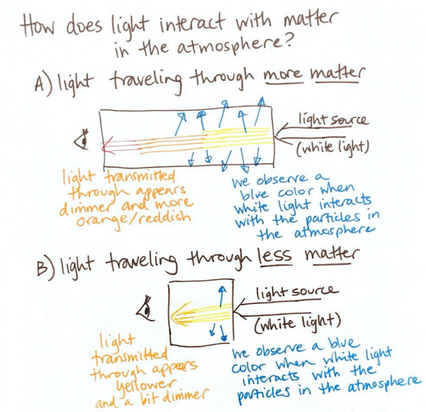
- The color (and brightness) of the Moon and Sun change near the horizon.
- Sunlight in space is whiter and brighter than sunlight we see from Earth's surface.
- Light travels through empty space even when there is very little or no matter.
- The atmosphere looks bluish during the day and from space.
- At sunrise and sunset, light from the Sun passes through the atmosphere at a shallow angle causing the light from the Sun to travel through more of the atmosphere.
- Sunlight dims in brightness and appears yellower, oranger, and then redder the more of Earth's atmosphere it passes through.

</td>
<td>

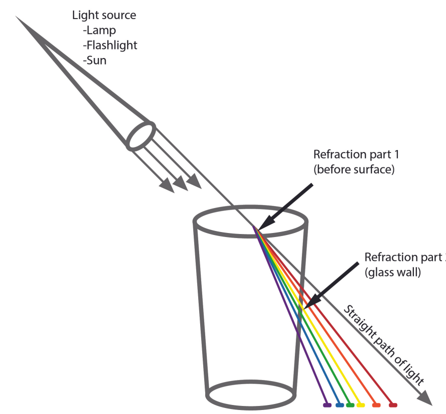


</td>
</tr>
</table>

⇓ **Navigation to Next Lesson:** We identified some variables that we think could cause changes in the color of light passing through the atmosphere that we want to investigate further.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 10 1 day **How does light interact with matter in the atmosphere?** Investigation	 *When we shine a white flashlight through narrow and wide clear tubs of water mixed with a little bit of white particulate matter (milk), the color of the light that's scattered off looks bluer than the flashlight color, and the light that transmits through gets orange or redder the more of that medium it travels through.*	We investigate the color and brightness changes we see as light travels through the Earth's atmosphere by using a flashlight to simulate the Sun and a rectangular bin of milky water to simulate the atmosphere. We use our investigation results to co-construct a model of light transmitting and scattering through the simulated atmosphere. We figure out: • Although sunlight is white in space, some of the colors are scattered out as it passes through Earth's atmosphere, so it appears yellower, oranger, redder, and dimmer in brightness, the more of Earth's atmosphere it passes through. • When we shine a light through a simulated atmosphere, the white color becomes oranger or redder the more "atmosphere" it travels through and the brightness of the light decreases the longer the path the light travels. • We observe a blue color when white light interacts with particles in the "atmosphere".	

⇓ **Navigation to Next Lesson:** When we shined white light into our simulated atmosphere, the light we saw scattered off the particles was bluish, and the light that was transmitted through was orangish, and the more particles there were, the less light we saw at all. So why are those different colors there after the light interacts with that matter?

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 11 2 days **How does the shape of a water droplet or an ice crystal cause sunlight to form into a rainbow?** Investigation	 *Sometimes when light strikes water droplets in the atmosphere, it produces rainbows. The individual colors are less bright than the original light.*	We investigate times, places and perspectives needed to see white light split into its component colors—making a rainbow. We investigate the effect that different materials and their shapes have on (white) light—causing it to change direction (refract) and sometimes make colors and rainbows. We conduct another investigation to recombine colors of light. We discover that combining light in different ways can change the overall color and brightness of the light that you see. We figure out: • Light interacts with water or glass of certain shapes/angles to produce rainbows. • Each color in the rainbow that is produced is less bright than the light that reaches the water/glass; the path that each color of that light follows is a straight line after it leaves the water or the glass. • Materials like water or glass must be able to separate white light into different colors and change their path based on their color. • White light is a combination of colors. • Combining different colors of light together results in more intense light (brighter).	

⇓ **Navigation to Next Lesson:** We think our discoveries could help explain why the Moon turns red and not totally dark during a lunar eclipse. We think we can use those ideas to explain other color phenomena.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 12

2 days

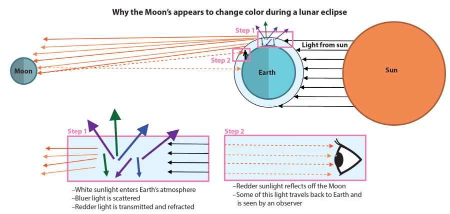
Why does the Moon always change color during a lunar eclipse?

Putting Pieces Together

Objects appear in different colors and in different places under water.

We celebrate the knowledge we have figured out in previous lessons that can help us explain color change during lunar eclipses. We evaluate models created in those lessons before co-constructing a new model of what is happening during a lunar eclipse. We prepare for and complete a transfer task. We figure out:

- Fish lures are used under water where light gets filtered through so they are made in specific colors that transmit better through water at different depths so they will be more visible to the eyes of the fish that are living at those depths than other colors.
- Fish appear in different positions under water than they actually are to an observer above the water because the light traveling from the fish to the observer's eye travels out of the water and into the air, bending—or refracting—as it travels from one medium (water) into another medium (air).



⇓ **Navigation to Next Lesson:** We applied what we figured out to explain other things we see happening under water but still have unanswered questions about patterns of objects we see in the sky and in space.

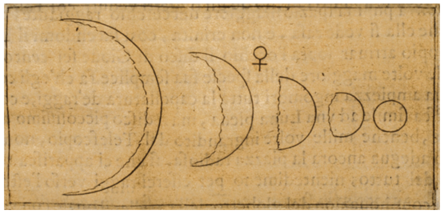
Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it

LESSON 13

3 days

What new patterns do we see when we look more closely at other objects in the sky?

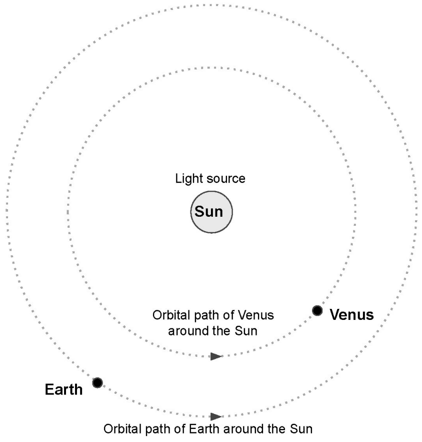
Investigation



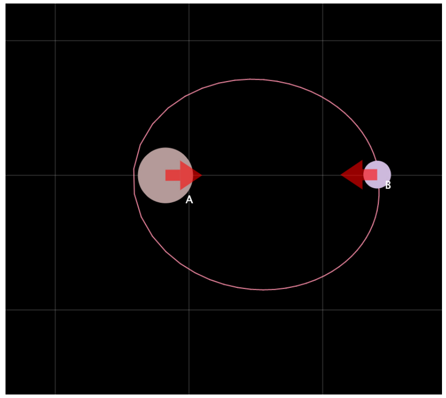
Various technologies have been developed over the last 400 years that help us observe changes in the position and appearance of planets in the sky as well as gather additional data from their atmospheres and surfaces.

We revisit unanswered DQB questions and decide to focus on other objects in our solar system. We gather information to identify connections and observations about one other planet, Venus. We notice additional patterns and record new questions about these. We use a model showing the relative position of motion of Venus and Earth in the system to explain these patterns. We analyze the scale properties of other planets to look for other patterns. We figure out:

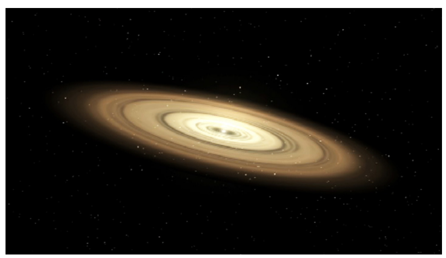
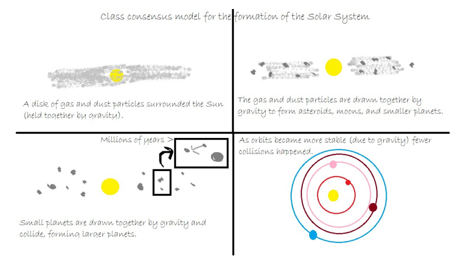
- Even though Venus and other planets in the sky look like stars, they move differently and their position changes.
- Planets closer to the Sun are rocky and small, and those farther out objects are large and gaseous.
- All solar system objects orbit the Sun in the same direction .
- There are nested patterns of orbits, but smaller objects tend to orbit larger objects.
- Most objects are orbiting the solar system on a similar plane.



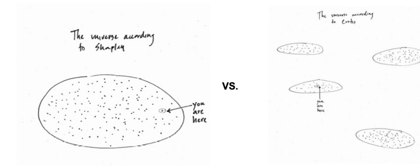
⇓ **Navigation to Next Lesson:** These patterns raise questions about why all of these objects have a steady orbital path and what mechanism(s) can help explain these patterns.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 14 2 days **Why do some solar system objects orbit planets and others orbit the Sun?** Investigation 	 *A computer interactive allows us to adjust the distance, speed, and mass between two objects and simulate the outcomes from simulated gravitational forces between them.*	We share initial ideas about patterns of motion in the solar system, which leads us to conduct a cause-and-effect thought experiment around those patterns. We use a simulation to investigate how changing distance and size affects an object's orbit around another object in the solar system. We build understanding as a class about the relationship between size, distance, and the strength of the force of gravity before demonstrating our understanding on a formative assessment. We figure out: • Gravity is an attractive force between all matter. • More massive objects have stronger attractive gravitational forces between them than objects that are less massive. • Closer objects have stronger attractive gravitational forces between them than objects farther away. • More circular orbits occur when there is the right combination between the force of gravity and the speed of the orbiting object.	

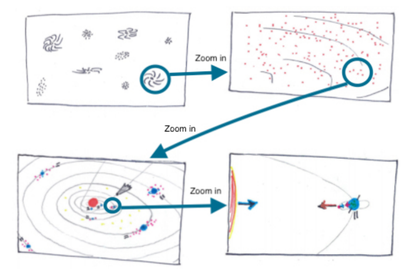
⇓ **Navigation to Next Lesson:** We figured out why objects in our solar system move the way they do now, but wonder if they always moved this way and if they will continue to move this way.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 15 1 day **How did the solar system get to be the way it is today?** Investigation 	 *There are many craters visible on moons and planets with little or no atmosphere on them. Simulations that include matter distributed across space in very small particles (dust, molecules, etc.) and gravity force produce outcomes that show how the motion and distribution of that matter changes over time.*	We analyze images of craters on the surface of Mercury and two moons. We watch a video showing the results of a computer simulation that models the formation of the solar system. We develop storyboards to support the claim that the solar system was formed from a disk of gas and dust, drawn together by gravity. We build a class consensus storyboard model of the formation of the solar system. We figure out: • The Sun formed in the center of a disk of gas. • The matter in the disk of gas began to collect to form bigger clumps of matter (e.g., pebbles) due to gravity. • These pebbles collided and clumped together to form smaller planets. • The smaller planets collided many times over several millions of years, resulting in the creation of larger planets, asteroids, and comets. • The collisions became less common as objects in the solar system as the objects had stable orbits.	

⇓ **Navigation to Next Lesson:** Though we made progress on questions on how the structure and motion of the objects in our solar system came to be, we still have questions about what else beyond our solar system. We want to see if telescopes can tell us if there are more patterns and objects in space beyond our solar system and beyond the stars we can see with our unaided eyes.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 16 1 day **What patterns and phenomena are beyond our solar system that we cannot see with just our eyes?** Investigation	 *Telescope photos show many distant clusters of stars located in what appears to the unaided eye to be empty space.*	We look at a photo taken by the Hubble telescope of blobs in the space between stars. We learn that these are galaxies, islands of stars much like the ones we see in the sky. We watch the *Tour of the Universe* to visualize how scientists model the universe at various scales. We notice that the universe appears to be organized into systems held together by gravity, separated by vast emptiness. We figure out: • Earth orbits the Sun, making the Sun and Earth part of our solar system along with other planets, asteroids, comets, and so forth. • Moons orbit planets, creating subsystems of the solar system. • Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe. • Gravity appears to dictate this organization because in the places where there is stuff, that stuff is held together by gravity.	 *Shapely was partially right because we are on the edge of the galaxy and the galaxy is held together by gravity.* *Curtis was partially right because there are many galaxies and the galaxy is held together by gravity.*

⇓ **Navigation to Next Lesson:** We figured out so much about how systems all over the universe are connected and work, and we want to put this all together and revisit how these patterns these systems produce are connected to our lives in order to close out our Driving Question Board.

Lesson Question	Phenomena or Design Problem	What we do and figure out	How we represent it
LESSON 17 2 days **How are we connected to all of the systems in space beyond the planet we live on?** Putting Pieces Together	 *From far away, Earth looks like a little pale blue dot floating in space.*	We make a classroom consensus model at various scales to show how gravity organizes the universe. We return to the DQB to take stock of how far we have come in this unit and then reflect on the unit and Earth's place in the universe. We figure out: • We can explain why there is a similar pattern in the motion structure and organization of the largest scale objects and systems in the known universe using the same interactions (gravitational forces that are acting on those objects). • We can answer many of our Driving Question Board questions!	

⇓ **Navigation to Next Lesson:** This is the last lesson in the unit.

LESSONS 1-17
31 days total