Curriculum Units by Fellows of the National Initiative
2022 Volume IV: Alien Earths

There's No "Space" Like Home

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Introduction and Rationale

“I think of space not as the final frontier but as the next frontier. Not as something to be conquered but to be explored.” – Neil deGrasse Tyson

I was sitting in my Alien Earths seminar on July 13, 2022, when the first James Webb Space Telescope photographs were released. When Yale professor, Sarbani Basu, pulled up the picture (see Figure 1) on the large screen, and it was breathtaking! She explained that the bright white spots with the “spokes” were stars, and the yellow and orange splotches were other galaxies. As I began to informally count the galaxies in my head and relish in amazement and wonder, Basu revealed that this image represents the patch of sky if a grain of sand is held up with an extended arm from Earth!

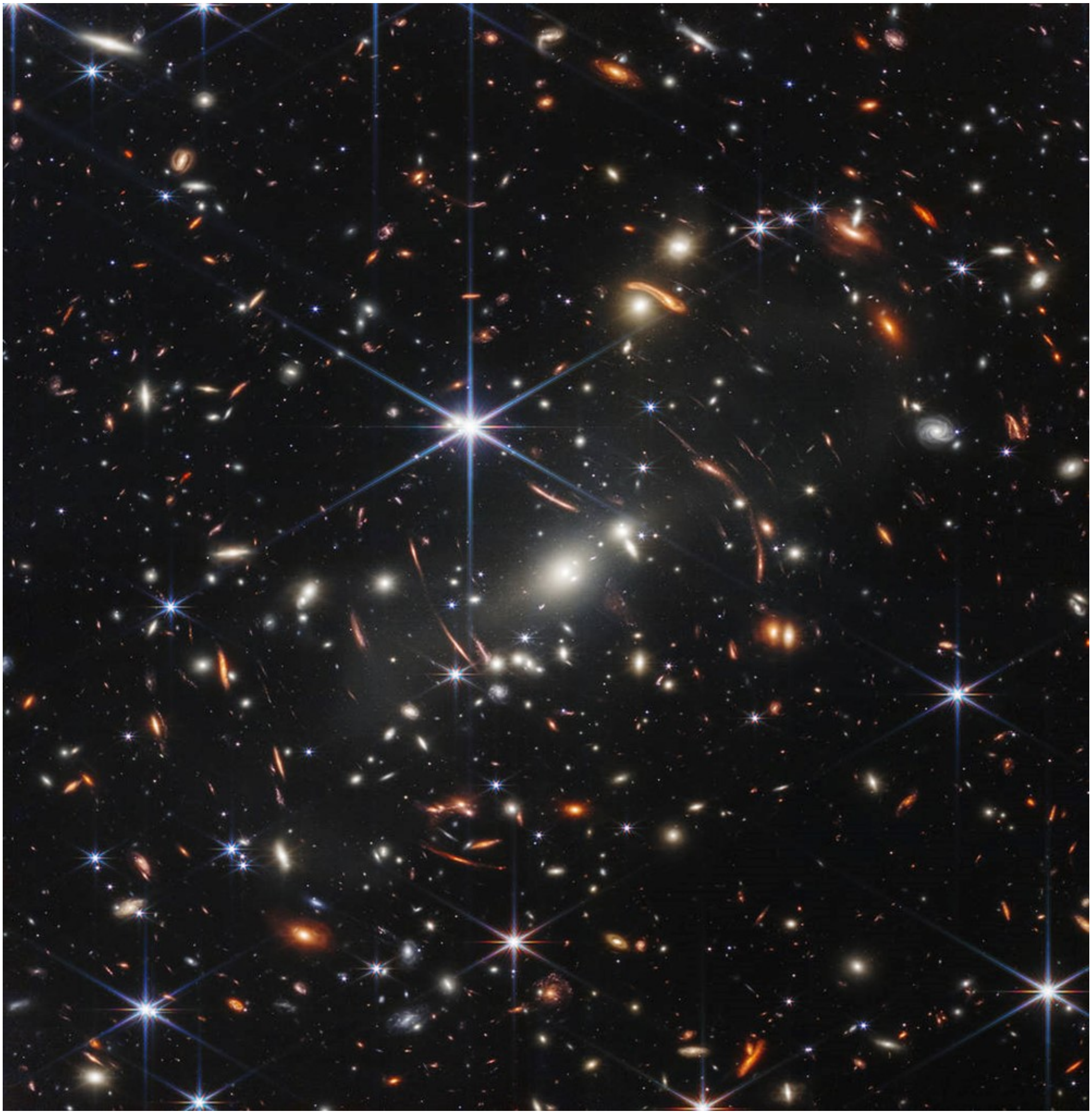

Figure 1: The first photograph from the James Webb Space Telescope Credits: NASA, ESA, CSA, and STSci

When I consider Neil deGrasse Tyson’s notion with the first photograph from the James Webb Space Telescope the implication of exploring the new frontier is unimaginable.

This curriculum unit I created in the Alien Earths seminar is designed for my fourth-grade students. It explores the eight planets, dwarf planets, moons, and exoplanets. Students will make comparisons and contrast celestial bodies. They will create scale models of the planets, and this modeling will help students grasp the vastness of our solar system and universe. The unit will also investigate the idea of habitability. In the last 25 years, NASA and other space agencies throughout the world have made some incredible discoveries. I want students to understand that our knowledge of the universe is constantly changing.

The creation of this curriculum unit is important for my students, so they can learn the most current information about planets and exoplanets. Not much has changed since I was in school regarding how solar systems are taught in elementary school. Our knowledge of the solar system was based on that one model, hence had many misconceptions. The knowledge of our solar system is expanding tremendously due to the research of astrobiologists, astronomers, and the work of NASA and other organizations around the world. The students, not only mine, deserve to learn up-to-date information that goes beyond the minimum state and national standards.

Demographics

My school, Mary Munford Elementary School, is in the west end of the city of Richmond, Virginia. It is a part of Richmond Public Schools. The students mostly come from middle-class homes with a lot of parental support, but there are also immigrants, students from low-income homes and a few homeless families. My school also serves low-incidence autistic students. The range of skill level in fourth grade is huge. A few students barely speak English, some perform two years below grade-level, and other students perform in the 99th percentile on norm-referenced tests for reading and math. My students' general knowledge also varies greatly. Some students read constantly and have opportunities to travel around the United States and to other countries, while others rarely leave Richmond.

Objectives

The standards that this curriculum unit will address are Virginia Standards of Learning (SOLs) as Virginia is one of the few states that did not adopt the Common Core Standards or the Next Generation Science Standards.

The primary standards that the unit addresses are SOL 4.5 which relates to planets, their movement, characteristics, order, size, and comparisons between them. SOL 4.6 focuses on the Earth, Moon, and Sun relationship and includes the position, age, and make-up of these three bodies. The unit will also connect to several related standards: scientific and engineering practices (SOL 4.1) students ask scientific and non-scientific questions. Design an object, tool, process or system to solve a problem. MS-ESS1-2 is the NGSS standard for middle school that covers the solar system.

Background Content

This section will provide content knowledge about our solar system, its formation, types of planets, habitability, and measurement.

Our Solar System

Our solar system is comprised of eight planets that orbit the Sun, moons that orbit planets, and asteroids, comets, meteors, and dust. The Sun is the center of the solar system, and the eight planets orbit around the Sun mostly in the same plane. Nicolaus Copernicus described the heliocentric, or Sun-centered, system in “On the Revolution of Heavenly Spheres” in 1543.

Formation

Scientists have been trying to understand and explain how Earth and our solar system came into existence. It is theorized that the Sun and planets formed from a solar nebula, or a spinning cloud of gas and dust (see Figure 2). This idea supports the fact that nearly all the planets travel around the Sun in almost the same plane. They also revolve in the same direction and most of the planets rotate on their axes in the same direction. While this scenario still holds, the details of the process are not known.

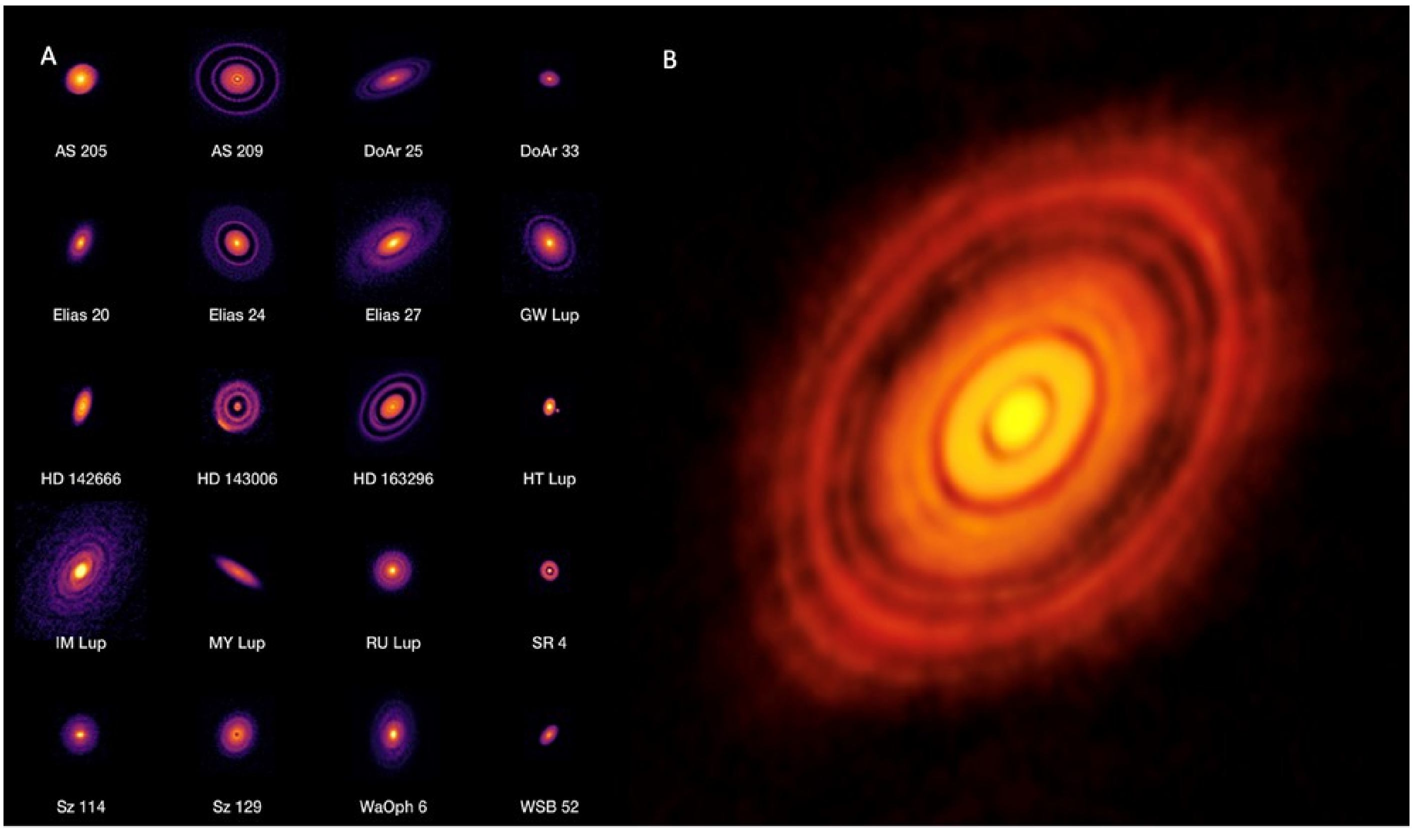

Figure 2: (A) Shows images of nearby protoplanetary disks (B) Shows the disk surrounding the star HL Tau. Credit: https://www.almaobservatory.org/en/press-releases/alma-campaign-provides-unprecedented-views-of-the-birth-of-planets/

As the field of exoplanets has emerged, technologies have improved, and data is continually collected from every planet and the far reaches of our solar system, scientists are piecing together and modifying their understanding of the origins of the solar system. Through the examination of young stars, scientists make observations, use models, and look for patterns to explain the origin of planets in the solar system.

When scientists take images using microwaves instead of visible light, the pictures show us young stars, many of which have spinning clouds of gas and dust around them. Computer models have shown that planetesimals, a precursor to a planet, form within clouds of gas and dust. The planetesimals gather, there are violent collisions and radioactive activity occurs, resulting in tremendous heat. The interior is so hot it melts, and a process called differentiation takes place where different materials become layered based on their density. The result is interior structures of planets that are different, depending on their chemical composition. Thus, in our solar system we have four terrestrial planets with rocky cores (Mercury, Venus, Earth, and Mars) and four gas giants (Jupiter, Saturn, Uranus, and Neptune).

The Sun

The Sun is an average-sized star. It is about 4.6 billion years old. The Sun is about 864,000 miles in diameter and about 110 Earths could fit across its diameter. The composition of the Sun is like the Earth's, but in much different proportions. The outer part of the Sun is made up of 73% by mass of hydrogen, 25% helium, and the remaining 2% is carbon, nitrogen, and oxygen, and they are mostly atoms. In the core, constant nuclear reaction has depleted hydrogen, and only 33% of the gas is hydrogen. The atoms are ionized, electrons are gained or lost, rendering them with an electronic charge. An example of ionization is rubbing a balloon on one's hair. Some electrons from the hair move to the balloon and its charge becomes negative.[1]

Unlike the Earth, the Sun does not have a solid surface or continents. It also does not have a solid core. Instead, the Sun consists of plasma, a hot, ionized gas. When the hot plasma spews from the surface it is called a solar wind. The charged particles from the solar wind can travel at a speed of one million miles per hour! They are attracted to Earth's magnetic field, particularly at the poles where it is the strongest. When the charged particles encounter molecules of air, the result is an aurora, or a glow known as the northern or southern lights.[2]

The structure of the Sun is like an onion. It has many layers that are from the inside out: the core, radiative zone, convective zone, photosphere, chromosphere, corona, and the sun atmosphere. The corona is seen during an eclipse, it is the bright halo of light. The corona is not visible at other times, because the brightness of the photosphere outshines it. The temperature of the corona can exceed one million degrees![3]

The Planets

The International Astronomical Union (IAU) passed Resolution 5A at the General Assembly Meeting in 2016. In that resolution, the IAU clearly defined the common bodies found in space. The IAU formally defines a planet as: "A 'planet' is a celestial body that is a) in orbit around the Sun, b) has sufficient mass for its self-gravity to overcome rigid-body forces so that it assumes a hydrostatic equilibrium (nearly round shape), and c) has cleared the neighbourhood around its orbit."[4]

Planets orbit mostly within the same plane. The image below (Figure 3) was created at NASA's Jet Propulsion Lab (JPL) to show the actual relative positions of solar system objects as of January 1, 2018. In (A) the face-on view shows the orbital paths of the terrestrial planets. In (B), the edge-on view, all of the planets are in the same plane, thus it looks like a line surrounded by the yellow dots that represent the asteroid belt.

The Inner Solar System

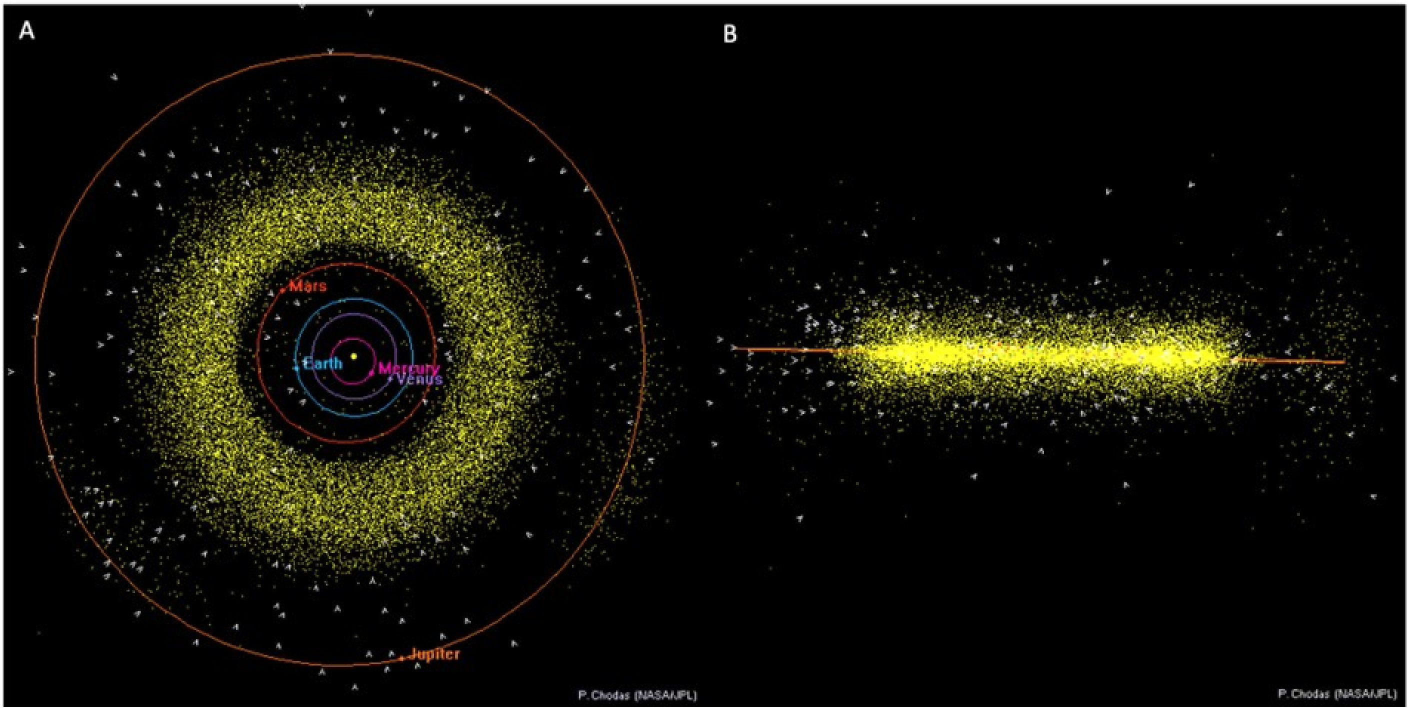

Figure 3: (A) shows the face-on view of the terrestrial planets and (B) shows the edge-on view. Credit: P Chodas (NASA/JPL)

Mercury is the closest planet to the Sun, and it is also the smallest. It is a little larger than Earth's moon and looks similar because it is heavily cratered. It is one of the four terrestrial planets. Mercury's elliptical orbit around the sun takes 88 days, making it the fastest orbit in the solar system. Mercury's rotation on its axis is slow. As a result, the sun appears to bob at sunrise (rise, set, rise) and sunset (set, rise, set) from certain parts of the surface.[5] Mercury is a moonless, ringless planet with a very thin atmosphere, which causes extreme temperatures and solar radiation. The chemical composition is mostly oxygen (O), sodium (Na), hydrogen (H), helium (He), and potassium (K). Mercury has water ice at its poles. From a habitability standpoint, Mercury has water ice and the building blocks for life, but its atmosphere and extreme temperatures remove it from consideration.[6] NASA's Mariner 10 and MESSENGER have explored Mercury, the former with a fly by and the latter with an orbit around the planet. The European Space Agency (ESA) and the Japanese Aerospace Exploration Agency (JAXA) have a mission to study Mercury underway. They launched BepiColombo, which is two spacecrafts riding together. They are scheduled to begin the orbit in 2025. They will study the surface and interior and the magnetic field.[7]

Venus, one of the rocky, terrestrial planets, is second from the Sun. It is also Earth's closest neighbor. Venus has similar size and density to Earth. However, there are vast differences between these two planets. Venus has a thick atmosphere which traps thermal energy, or heat, and causes a runaway greenhouse effect. It is the hottest planet with a surface temperature of about 900º F! The atmosphere is toxic. It is made of sulfuric acid, which is why it is yellow and smells like rotten eggs! The air pressure on Venus is more than 90 times Earth's and is comparable to going one mile below the ocean. Another difference is the rotation. Venus rotates backwards on its axis from Earth and most other planets. As a result, the Sun rises in the west and sets in the east! Venus rotates slowly; one day on Venus is equivalent to 243 Earth days. Surprisingly, it orbits the Sun in 225 Earth days, which means that one day is longer than one year on Venus.[8] Since Venus is our closest neighbor, it is no surprise that it was the first to be explored by spacecraft. The explorations began in 1962 and continue today. They have been fly-bys as anything that lands on Venus cannot survive long due to the extreme heat.[9]

Earth, the third planet from the Sun, is the largest of the terrestrial planets and the fifth largest overall. It is the only planet known to have life. Earth's distance from the Sun (150 million Km), its protective atmosphere, and the presence of liquid water on its surface make it habitable. The surface of Earth is active and is constantly changing. There are mountains, canyons, plains, and other landforms. While there are many geological features on Earth, water covers the majority of this planet.[10]

Mars is known as the "red planet" because it gets its color from oxidized iron (rust) and the dust. Its name comes from the Roman god of war. Mars is the fourth planet from the Sun. It has a thin atmosphere and its distance from the Sun makes it extremely cold. It is about half the diameter of the Earth. Scientists do not expect to find life on Mars but are trying to determine if it existed in the past. Mars has a large network of canyons and riverbeds. It is believed that billions of years ago, Mars not only had a thicker atmosphere, but also was warmer and wetter.[11] Mars has been explored more than any other body in our solar system. Many rovers have explored Mars. Opportunity and Spirit were launched in 2003 with the goal to search for water on Mars. More recently, NASA has sent Perseverance and Curiosity. The former traversed 293 million miles in 203 days and reached Mars on February 18, 2021. Perseverance is the largest and most advanced rover to visit another world. In addition, NASA has sent a lander, called In Sight, and a helicopter called Ingenuity. The helicopter hitched a ride on Perseverance in order to reach Mars. Numerous other space agencies and countries have also explored the Martian world.[12] It takes 24.6 hours for Mars to rotate on its axis, which is close to a day on Earth. However, a Martian year is nearly double a year on Earth! Mars has two small moons which are shaped like potatoes! Their odd shape is because they do not have enough mass for gravity to make them spherical.[13] Dust storms and atmospheric conditions have created some amazing topography on Mars. The Valles Marineris is about 10 times the size of the Grand Canyon and would stretch from California to New York. Mars is also the home of the largest volcano. It is called Olympus Mons and is three times larger than Mt. Everest.[14]

Jupiter is the largest planet in our solar system and the fifth planet from the Sun. It is more than five times as far from the Sun as Earth is, or 5.2 AU (astronomical units). Jupiter rotates very quickly and one day is only 10 hours, but it takes about 12 Earth years to orbit the Sun.[15] Jupiter is known for its beautiful swirls which are comprised of ammonia and water. The atmosphere contains hydrogen and helium. There is no solid surface on Jupiter. The Giant Red Spot seen in images of Jupiter is a massive storm that is larger than Earth. For years, it was believed that Saturn was the only planet with rings, but all the gas giants have rings. Jupiter's are faint. Jupiter cannot support life, but it is quite possible that some of its 75 moons may be capable of doing so.[16] There has been quite a bit of exploration of Jupiter. This giant planet has been visited by nine spacecraft. Of these nine, seven have flown by and two have orbited the planet. The most recent to orbit Jupiter is Juno, which arrived in 2016.[17]

Saturn is the sixth planet from the Sun is the second largest and has thousands of stunning rings. Its diameter is nine times greater than Earth's. Saturn's day is a little longer than Jupiter's at 10.7 hours. Its year is 24 Earth years, which is twice Jupiter's. Saturn has no solid surface and is primarily made up of hydrogen and helium. The atmospheres of Saturn and Jupiter are similar. Saturn hit the lottery when it comes to moons. It has 53 known moons, additionally 29 more are waiting to be confirmed. These moons may support life, but Saturn will not.[18] Saturn has been explored by Pioneer II and Voyager 1 and 2. These spacecrafts did fly bys.

Beginning in 2004, Cassini has spent 13 years orbiting Saturn 294 times.[19]

Uranus is the seventh planet from the Sun. It is the third largest in our solar system and is a gas giant. More specifically, it is an ice giant. Uranus has a small, inner core surrounded by helium, hydrogen, and some methane. The icy layer's chemical composition is water, methane, and ammonia. Uranus is about four times the diameter of Earth.[20] Uranus takes 84 Earth years to orbit the Sun. It takes 17 hours to rotate on its axis. Oddly, it rotates east to west and spins on its side. Twenty-seven known moons orbit Uranus, which also has 13 rings. The Voyager 2 spacecraft has flown by Uranus.[21]

Neptune is the eighth planet from the Sun. This planet with its deep, blue coloration is cold and home of the strongest winds in the solar system. The winds can reach 1,200 miles per hour! It rotates quite quickly in 16 hours. Neptune lies more than 30 times as far from the Sun as Earth (2.8 billion miles), and its journey around the Sun lasts 165 Earth years.[22] It is considered a gas giant. It has a small, rocky core, surrounded by icy material. The gaseous part is hydrogen, helium, and methane.[23] Fourteen known moons orbit Neptune. In addition to five faint rings, it has four ring arcs. The ring arcs are rings where parts are faint or invisible. Voyager 2 has visited Neptune.[24]

Moons

A moon is a natural satellite that orbits a planet or an asteroid. Most moons likely formed out of the disks of gas and dust around the planets. Some moons were "captured" by the gravitational force of larger bodies within the solar system. Other moons form from collisions between larger objects. Our solar system has more than 200 known moons. Mercury and Venus are the only planets in our solar system that do not have any moons. This is most probably due to their proximity to the Sun. The orbits of the moon will not be stable and the strong gravitational force of the Sun would result in the moons being captured by the Sun. A brief description of each planets' moons is noted in the above planet descriptions.[25]

It is no coincidence that Jupiter and Saturn, the two largest planets in our solar system, have the most moons. Jupiter has some unique moons. Ganymede is the largest known moon, Europa is an ocean moon, and Io is a volcanic moon. Some of Jupiter's moons have highly eccentric orbits, or highly elliptical orbits. Some orbit backwards, in the opposite direction of Jupiter. Neptune's largest moon, Triton, was captured by gravity and orbits in the opposite direction of its planet. Saturn's moon, Phoebe, was also captured in the same way. Saturn's largest moon, Titan, is the second largest in our solar system. It is the only moon with a thick atmosphere.

Earth's moon is believed to have formed as a result of a collision between a Mars-sized object and Earth several billion years ago. A collision that knocked Neptune on its side likely led to the formation of some of its moons.[26]

Dwarf Planets

The definition of dwarf planets that was formalized in 2006 in Resolution 6A of the International Astronomical Union (IAU) General Assembly Meeting. "A 'dwarf planet' is a celestial body that a) is in an orbit around the Sun, b) has sufficient mass for its self-gravity to overcome rigid body forces so that it assumes a hydrostatic equilibrium (nearly round) shape, c) has not cleared the neighbourhood around its orbit, and d) is not a satellite."[27]

The most well-known dwarf planets are Ceres, Pluto, Eris, Haumea, and Makemake. Except for Ceres, these dwarf planets lie in the Kuiper Belt. Ceres is located within the main asteroid belt between Mars and Jupiter. There are other known dwarf planets and likely thousands more waiting to be discovered.[28]

Pluto is the most famous dwarf planet that is because it was classified as a planet for 76 years, from 1930 until 2006. Then in 2006, Pluto was demoted from planet status, and reclassified as a dwarf planet. Why? Pluto is smaller than the Earth’s moon. This icy dwarf sits out beyond the gas giants, and it is tilted (57º) more than the other planets. Its orbit is more elliptical which is why it sometimes orbits the Sun closer than Neptune. In Figure 4 (A), the orbital lines clearly show Pluto’s orbit traversing inside of Neptune’s orbit. In (B) Pluto’s orbit is elliptical and highly tilted. In fact, Pluto’s orbit is similar to other dwarf planets or “plutinos” that have been discovered so far.[29]

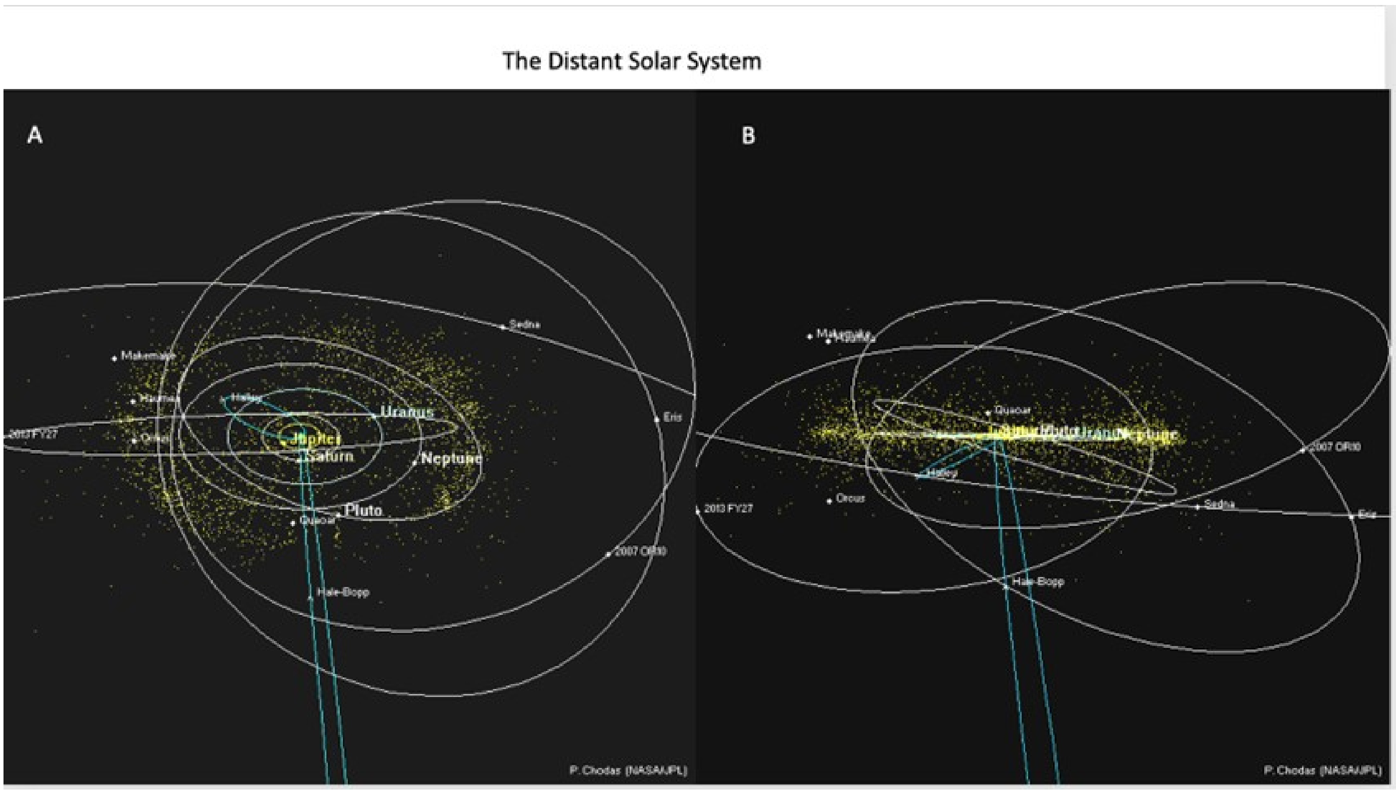

Figure 4: (A) Face-on view of the distant solar system (B) Edge-view of the distant solar system Credit: P Chodas (NASA/JPL)

The surface of Pluto is extremely cold. Scientists do not believe life could exist on Pluto. However, the interior is warmer and perhaps an ocean may lie deep within this body. Pluto has five moons and no rings.[30]

Ceres is located within the asteroid belt. It was discovered in 1801. At first it was believed to be a comet, but within a year, it was thought to be a planet. After about a year it was deemed an asteroid. Then for years, it was believed to be an asteroid. In 2006, its classification changed yet again. It currently is the only dwarf planet within the inner solar system.[31]

Eris was first discovered in 2005 and was colloquially called Xena. Scientists debated the classification of this new world. As a result, the IAU clarified the definition of a planet, demoted Pluto, and decided that Eris and Ceres were dwarf planets. Eris is fittingly named for the Greek goddess of discord.[32]

Makemake is located within the Kuiper Belt. This icy body is slightly smaller than Pluto and orbits beyond Neptune. Makemake was discovered in 2005 and along with Eris sparked the debate that led to the new category of dwarf planets.[33]

Haumea is about the same size as Pluto. Like Makemake, Haumea is located within the Kuiper Belt beyond Neptune. It was discovered in 2003.[34]

There are many other dwarf planets in our solar system, and it is believed that most of them have not even been discovered yet.

Exoplanets

Another class of planets is exoplanets, or planets that are outside our solar system. They typically orbit another star. According to Adam Frank, "Pretty much every star in the sky hosts at least one planet."[35]

In 1995, 51 Pegasi b was discovered. It was the first exoplanet found to orbit a normal star, and not a pulsar or a dead star. To date, there are 5,060 known exoplanets.[36] Exoplanets are named for their star (51 Pegasi) and b denotes the first exoplanet discovered orbiting that star. If there was a second exoplanet orbiting the same star it would use the letter c.[37]

Based on our solar system, one would think that larger gas giants are farther away from the Sun. However, with the discovery of 51 Pegasi b, we now know that this Jupiter-sized exoplanet is 10 times closer to its star than Mercury is to our Sun, thus defying our thinking that all gas giants orbit far away from their star.[38] There are "hot Jupiters," "hot Neptunes," "super Earths," "super Saturns," and systems containing only smaller, rocky planets. The most common size of exoplanet discovered to date is the "super Earths," or "mini Neptunes," as they are between the size of Earth and Neptune. In our solar system there aren't any planets of this size. These new discoveries are changing what we know about our universe and our understanding of planetary system formation.[39]

Bernard Le Bovier de Fontenelle, a French philosopher who lived from 1657-1757, was way ahead of his time. He wrote, "The fixed stars are so many Suns every one of which gives Light to a World," and he went on to explain that each star would have a planet and inhabitants.[40] With the new discoveries of dwarf planets, other moons, and exoplanets, the idea of life beyond Earth seemingly grows exponentially. People wonder, is extraterrestrial life possible? What is life?

Habitability

People have been studying the night sky, trying to understand how vast it is and what may lie in our universe. Epicurus, a Greek philosopher who lived 341–270 B.C.E. believed, "There are infinite worlds both like and unlike our own."[41] Since ancient times, people have been pondering the question, "Are we alone?" While scientists can detect Alien Earths, the quest to discover if life exists on another world is currently more elusive. Given the vast distances to planets outside our own solar system and the difficulty to study them, it seems more likely that we would be able to find some form of life within our own solar system. Some of the moons that orbit other planets appear to have more potential for life than the planets within our solar system.

If we are looking for similar life to that on Earth, then we need three main conditions: water, an atmosphere, and temperatures hospitable to life. Jupiter's moon, Europa, and Saturn's moon, Enceladus, are both good candidates. Scientists believe that beneath Europa's icy crust lies an ocean with liquid water or slushy ice.[42] Enceladus has water beneath the surface that spews out in jets. The water comes from an ocean. It is believed that there are hydrothermal vents similar to those below Earth's ocean floor.[43]

Measurement and Scale

One of the challenges with teaching the solar system is that the size of the planets and the distance between them are so large. It is difficult for adults, let alone children, to comprehend the magnitude of large numbers. In order to help the students to grasp these concepts, they will compare planets to the Sun and to each other. In Table 1, the diameter of each planet is listed for the teacher's reference. Students can practice comparing and ordering numbers by ordering the diameters then determining to which planet each diameter belongs. Once the students determine the respective diameters, the students will be taught how to use the diameters to calculate the relative size of each planet.

If Earth is 1 unit and has a diameter of 12,756 Km, then to calculate the relative size of Mercury the students would use a calculator and divide 4,879 Km by 12,756 Km, or 4,879 Km ÷ 12,756 Km. The answer is 0.38248667. The students would round the decimal to the nearest tenth or 0.4. Once the students have determined the relative size of each planet, the students will use the information to create a scale model. This will utilize the multiplicative comparison (i.e. Uranus is about 4 times the size of Earth) and a concrete tape diagram, as seen in Singapore Math and in Eureka Math to create a scale model of the relative sizes of the planets. This activity is explained in the activity section of the unit.

The students will then use astronomical units (AU) to create a distance model. For this model, the Sun will be the origin, and represent zero. One AU is defined as the average distance between Sun and the Earth. So, Earth would be one AU. Mercury would represent 0.39 of an AU. Students could scale the distances between a planet and the Sun to calculate the AU's, but for this unit, the students will just use the information provided on the chart.

Table 1: Displays planetary size information for scale models.

Planet	Diameter (Km)[44]	Distance in AU[45]	Size Relative to Earth[46]
Mercury	4,878	0.39	0.4
Venus	12,120	0.72	1
Earth	12,756	1	1
Mars	6,787	1.52	0.5
Jupiter	142,984	5.20	11
Saturn	120,536	9.54	10
Uranus	51,118	19.18	4
Neptune	49,660	30.06	4

Information compiled from various sources.

For reference, the Sun has a diameter of 1.39 million Km and its relative size is about 110 times the size of the Earth.

Design Thinking

The design process is a structure for problem solving and testing. The goal is to develop a solution that solves a societal problem, which may have multiple solutions. The Science and Engineering Practice in the Virginia Standards of Learning uses a model based on the National Aeronautics and Space Administration (NASA) engineering design model. There are eight steps which are: 1) Define (the problem), 2) Imagine (brainstorm a solution), 3) Research (research the problem and possible solutions), 4) Plan (a device to address the problem), 5) Build (a device to address the problem), 6) Test (to see if the device works), 7) Improve (the device), 8) Share (communicate results to stakeholders and public).

Teaching Strategies

Design Thinking and Modeling

Students will be introduced to Design Thinking through a workshop model. The steps of the design process will be modeled and explored. The students will apply the Design Thinking process throughout the scale modeling and the rocket design and construction parts of the unit. Some of the activities will use an abbreviated version of Design Thinking. Other activities will require students to go through the entire process.

Collaborative Groups

Ideally students will work in collaborative groups. This will allow them to help each other and talk through their ideas, iterations, and calculations.

Guest Speakers

It is always nice to engage with experts in the field. For this unit, I read *Chasing Space* by Leland Melvin. He is a former NASA astronaut and graduate of my alma mater, the University of Richmond. I am hopeful that he can visit my school and speak to my students. Another option is a friend who is an aeronautical engineer and is involved with rocket launches. Either of these potential guest speakers will engage the students and help them to envision careers that involves astronomy.

Guided Research Projects/Presentations

The students will follow guidelines to conduct research and put together a multi-media presentation about bodies in the solar system.

Activities

The students will begin learning background information about planets, dwarf planets, and exoplanets. The activities are designed to not only teach them characteristics of the celestial bodies, but also to show them the vastness of the solar system. Through the modeling activities, the students will connect mathematical and measurement skills.

Day 1: Teach content with Google Slide

Day 2: Teach content with Google Slide

Day 3: Students collect data on planet.

Days 4 & 5: Students make Google Slide to Compare and Contrast

Day 6: (Activity 1 below) Students will be given an incomplete data chart and shown how to complete the calculations. The students will complete the chart. The students will order cards with the diameters of each planet (math practice- comparing larger numbers).

Day 7: Make playdough using its recipe and customize the colors to match the planets. It would be helpful to label the GladWare, or similar container, with the color and the corresponding planet name.

Day 8: (Activity 2 below) Make tape diagram with playdough and a scale. Then turn the tape diagram into a scale model of the planets.

Day 9: (Activity 3) Use AU distance to create a model of the distance from the Sun.

Day 10: A guest speaker will visit the class or school.

Day 11: How do we travel to planets, dwarf planets, and moons? Introduce Design Thinking and design a rocket.

Day 12: Build a rocket. In *Chasing Space* there are two different ways to make rockets. There are also instructions to build a rocket launcher in the book and online. Rocket launchers are also sold online.

Day 13: Build a rocket.

Day 14: Launch a rocket.

Day 15: Assessment

Activity 1:

This activity is from Day 6 of the above list. The students will be given a handout of the diameters of the planets. It will only have the diameter. Students will have to cut out the cards and order the diameters from least to greatest. Then they will have to determine which diameter goes with each planet based on what they have learned about the planets. Then the class will share out answers to check for correctness.

Students will be given an incomplete table, like Table 1 in the curriculum unit. The AUs for each planet will be listed, but the diameter and size relative to the Earth columns will be blank. The teacher will display the table for the class and discuss the meaning of diameter, AU, and size relative to the Earth. The diameter is the length of the chord (line segment with two points on the circle) that goes through the center of the circle. Planets are spherical, but if the planet is cut in half, the cross-section is a circle. An AU is an astronomical unit. One AU is equivalent to the distance of the Earth from the Sun. The size relative to the Earth's is a comparison based on the Earth representing one.

The students will write the diameter of each planet on their table. The teacher will call attention to the Earth. It has a diameter of 12,756 Km, distance in AU (1), and size relative to the Earth (1). The teacher will model how to calculate the relative size of the other planets. Mercury has a diameter of 4,879. So, to calculate the size relative to Earth the students will use a calculator to divide 4,878 Km by 12,756 Km. The calculator will display 0.38240828, and for practical purposes, the answer will be rounded to the nearest tenth. The students may need to be taught decimal place value and how to round to the nearest tenth. The students should round the answer to 0.4 and add that to their table. For Venus, the students will divide 12,120 by 12,756 and get 0.95014111. This will round to 1. The students should continue to complete the table in this way. Please note that the students will need this table for the Activity 2 (Day 8).

Activity 2:

For this activity the students will need the table from Activity 1 and the playdough that they made. They will also need a scale to measure grams. It is recommended that they work in collaborative groups of 3-4 students. First the students will create a multiplicative comparison tape diagram. Then the tape diagram will be turned into the planets, so that they are to scale.

The teacher will model how to make Earth, which represents one. For this activity we will make Earth 4 grams. Take a small piece of playdough of the color that corresponds to Earth. Use the scale to get the weight of the playdough to equal 4 grams. I chose 4 grams randomly. One gram would be too small when creating Mercury and Mars. Form the playdough into a small rectangular prism. Now select the playdough for Mars, which has a size relative to Earth of 0.5. Ask the class how many grams would represent Mars. Since 0.5 is equivalent to ½ and ½ of four grams equals two grams, weigh out two grams. Another way to calculate this is to multiply (with paper and pencil or a calculator) 0.5 ´ 4g = 2g. It may be helpful to model this method, so the students will know how to determine the weight of Mercury.

The students will continue to make a piece of “tape” to represent each of the eight planets. Explain that the Sun would be 110 times the Earth or about 440 grams of playdough, but we will not model the Sun with playdough. When the tape diagram is complete, the students will then roll each piece of “tape” to form a planet. (Please note that the weight is not to scale based on the mass of the planets. It is designed to bring in measurement and to help the students create more uniform chunks of playdough.) The model will be to scale based on the “size relative to Earth.” The students can then order and label the planets correctly in size order from smallest to largest. Next, they can order and label the planets in order from the Sun. Set the models of the planets aside, as we will use them to for the next activity.

Activity 3:

The students will create a scale model to represent the distance from the Sun. For this activity, the students will need their Table from Activity 1, their planet model from Activity 2, a meter stick, sidewalk chalk or paper and a supply of pencils. A large outdoor space (at least 30 meters in length preferably sidewalk or pavement) will also be needed. If you use a grassy area, you may want a supply of pencils to help mark the Sun and every 10 meters. You may also want paper on which to place the planets to make them visible. It may be helpful for each group to carry their planets in a GladWare, or some other type of tub.

Explain to students that for this day’s activity, we will use the AU column of the table to create a scale model to show the distance from the Sun. For this lesson, one meter will represent one AU. Remind students that one AU is the distance from the Sun to the Earth. Ask the class how many centimeters are in one meter (100 cm.). So how many centimeters would represent the distance of Mars from the Sun for our model (39 cm.)? Then ask the students how many centimeters would represent the distance of Mercury from the Sum in our model (1 meter 52 cm.)? Use sidewalk chalk to make a line that represents the Sun or the origin (0 AU). Then measure one meter, and place planet Earth at this location. Then determine the location for Mercury, Mars, and Venus and place these planets at the correct location. Explain to the class that as the gas giants are added to the model, it may be helpful to measure ten meters, twenty meters and thirty meters and mark the location with sidewalk chalk (or a pencil if on grass). Suggest to the class that if they are making their model on a grassy area, that they may want to place each planet on a piece of paper so it will be visible and will not get lost. Students should continue in this way to make the scale model. A modification is to make one model as a class.

Activity 4:

The students have learned about our solar system and exosolar planets. Ask the students, if the planets and exoplanets are so far away, how can we travel to them? The class will discuss sending rockets to these faraway worlds. For this activity, students will follow the Design Thinking steps to design a rocket using a two-liter soda bottle. There are eight steps which are: 1) Define (the problem), 2) Imagine (brainstorm a solution), 3) Research (research the problem and possible solutions), 4) Plan (a device to address the problem), 5) Build (a device to address the problem), 6) Test (to see if the device works), 7) Improve (the device), 8) Share (communicate results to stakeholders and public).

The students will explore the question, “How do we travel to other worlds?” Next, they will brainstorm and search online for images of rockets. For step three, they will research the best shape for the fins of the rocket. Once the students have drawn a plan, they should think about the materials they will need to build their rocket. Again, they may want to research the fins as they consider what material to use to make them. The next step will be to build the rockets!

Materials for Classroom Use

Mixing bowls, flour, oil, cream of tartar, salt, gel food coloring, GladWare, scale, meter sticks, sidewalk chalk, 2-liter soda bottles, poster board, low-temperature glue gun, tape (masking or duct), scissors, safety glasses, markers, modeling clay, and a rocket launcher or materials to make one.

Resources for Teachers

Playdough recipe https://kidsactivitiesblog.com/206/play-dough/

Chasing Space Young Readers Edition (see bibliography)

NASA’s Unexpected Discoveries on Jupiter video https://www.youtube.com/watch?v=NmHOj8VQvNE

https://spaceplace.nasa.gov/

Appendix for Implementing District Standards

Virginia Science Standard of Learning (SOL) 4.1

The student will demonstrate an understanding of scientific and engineering practices by a) asking questions and defining problems b) planning and carrying out investigations c) interpreting, analyzing, and evaluating data d) constructing and critiquing conclusions and explanations e) developing and using models f) obtaining, evaluating, and communicating information

This standard is new in the 2018 standards. The engineering practices are to be woven through the content and taught all year long. The engineering practices are designed to apply science skills to solve a problem or to make a prototype for an object, tool, process, or system. The rocket activity will implement the engineering practices.

Science SOL 4.5

The student will investigate and understand that the planets have characteristics and a specific place in the solar system. Key ideas include a) planets rotate on their axes and revolve around the sun; b) planets have characteristics and a specific order in the solar system; and c) the sizes of the sun and planets can be compared to one another.

The curriculum unit's focus is the solar system and planets. The unit was designed to address this standard through modeling, research, and Design Thinking.

Science SOL 4.6

The student will investigate and understand that there are relationships among Earth, the moon, and the sun. Key relationships include a) the motions of Earth, the moon, and the sun and d) the relative size, position, age and makeup of Earth, the moon, and the sun.

The students will explore the relationships and the movements of the planets, moons, and the Sun.

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