We Are All Just Star Dust, and That Makes Us Special

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Introduction/Overview

Throughout human history, the cosmos have been a source of awe and wonder. From ancient civilizations through modern times people have looked up and wondered what is out there, and will we ever see it for ourselves. Children experience this awe from the first time they notice the Sun moving across the sky, or see the Moon as it seems to change size and shape in the night sky. Add to our own observations of the cycles in the sky the many levels of science fiction and fantasy centered on the possibilities of space travel and extraterrestrial beings, and you may very well have set the stage for a lifelong interest in science and space.

Anyone who has taken a high school-level chemistry or physics class realizes that everything in existence is made up of the same very basic particles and is subject to the same immutable laws. This most basic tenet of scientific understanding is also a jumping off point for some of the biggest philosophical questions with which humanity has ever been faced. The how and whys of our existence are all contained in that fact: we are exactly the same, at an atomic level, as every other thing in the universe. I have always found the idea that, with all of the differences between me and my surroundings, everything is actually the same as me with just a shuffle in the way things are put together, an unending source of fascination. To look at the stars, or feel the heat of the Sun, or watch a flower grow and know that the electrons, protons, and neutrons in them are the same as the ones in me, fills me with questions. To extend that idea further, not only am I made up of the same subatomic particles as the Sun, but my particles were created in a star.

One of the main topics of study for science in the third grade is the Solar System. This is an idea which gets the students excited, and one they look forward to studying. While the topic is interspersed in our reading and science curricula, there is a broader chance to explore the many systems that make up our lives and existence. In this unit, students have a chance to integrate our study of the Solar System and many other aspects of their life, and will see that science is not a standalone subject, but incorporates all parts of our lives. By studying the "building blocks" of the universe, students are given a chance to begin to analyze how all living and non-living things are connected in unexpected ways, and how we can begin to understand those connections through observation and questioning.

The science portion of this unit starts with a brief study of atomic and molecular structure at an elementary level, and how everything is made up of subatomic particles in different combinations. The unit then proceeds to follow the historical understanding of the Solar System from the ancient mythology based around the cycles observed in the sky, before moving on to the more scientific geocentric, or Earth-based, model of the Solar System and ending with our modern understanding of a heliocentric, Sun-centered Solar System.

One of the very important understandings of this unit is to understand that everything that was known about space until approximately 50 years ago, was extrapolated solely from observation and drawing conclusions. We have never been able to go and see with our own eyes, or touch, or run tests on what is in our Solar System. Scientists over the years have had to use what they know of Earth, matter, and cycles, and combine them with observations of space in order to create our current body of knowledge.

Class background

The school at which this unit was developed, Barringer Academic Center, is an urban elementary school in the Charlotte-Mecklenburg School System of North Carolina, housing a K-5 partial talent development magnet program, leading to a student body comprised of approximately 600 students from throughout Charlotte, in 4 very different programs. The neighborhood home school segment of the school is primarily low income African-American families with many students receiving free or reduced lunch, and a segment of the population receiving services from "A Child's Place", a group working with homeless and displaced students, as well as school counselors, psychologists, and social workers. The magnet program at our school consists of a "Learning Immersion" lottery program for grades K-2, a "Talent Development" program for academically and intellectually gifted students in grades 3-5, and a unique "Horizons" program for highly gifted students in grades K-5. The combined programs lead to a student population approximately 75% African American, 10% Caucasian, 7% Asian, and 8% other races including Hispanic and mixed. Including all magnet and neighborhood programs, the school has about 70% of students receiving free or reduced lunch.

This unit was written for a class of high achieving third graders in an academically and intellectually gifted magnet program. The class consists of seventeen 8-10-year-olds, split nearly equally between boys and girls. The students come from a wide variety of backgrounds, culturally, socio-economically, and educationally. Many of the students have a solid basis in science, with reading and math skills above the average for their level in school. While this lesson was created with this group dynamic in mind, most if not all of the activities could be easily adapted to fit a class from a lower-level third grade class, similar to many of the other classes in my school, up into middle and possibly even high school. Many of the activities and ideas presented in this unit lead to the highest levels of thinking and questioning, and could lead to discussions on historical, philosophical, and very relevant current scientific findings.

We are lucky in that we were chosen for a grant which has provided a number of our classrooms, including the one in which this unit was developed, with SMART interactive whiteboards. This allows for a high level of technological integration, but many of the aspects of this unit can be done with limited computer access. The students also have access to a Science Lab as a part of their specials rotation, attending for one 45-minute class-period during every 6-day rotation. There are numerous interactive science websites with videos, virtual experiments, and spatial exploration to support the learning of abstract science concepts without having the money for consumable science resources and permanent equipment.

The science curriculum both in my base class and in Science Lab are based on the North Carolina Standard Course of Study, with resource units from the Department of Public Instruction.

Objectives

This unit is designed to meet various third grade North Carolina Standard Course of Study (SCoS) goals and objectives in science, math, reading, and social studies, as well as meet the differentiation needs of a diverse group of learners with differing backgrounds and critical thinking skills. It is written as a 9-week long unit covering one quarter of the science curriculum for the year.

Through this unit, students will develop an understanding of the Earth as a planet, and its place in our Solar System. They will understand the relationship between the Earth, its moon, and our star – the Sun. Through hands-on modeling and personal observations, the students will learn what makes the Sun, quite literally, vital to our existence and survival.

Students will understand that all matter is made up of atoms, and will have a basic understanding of how atoms were created, and combine to create everything around us. We will look at atoms and molecules as systems that follow certain rules and expectations, and will expand that concept to look at planetary systems.

Students will apply the highest level thinking skills to analyze and evaluate different ideas, understanding, and theories about our Solar System throughout history, and use this understanding to create working models of our Sun-centered Solar System.

Rationale

Science is one of the most exciting and interesting subjects taught in school, and yet with the push toward accountability and standardized testing, all too many schools have found the need to push science to the back burner while they focus on literacy and math in preparation for those tests. In the years since No Child Left Behind went into effect, the required hours of literacy and math instruction in the classroom have lead to science instruction being required only 45-minutes per week. So while these students get less and less science instruction, the addition of the fifth grade science end-of-grade test has left teachers scrambling to catch up.

Although reading and math can lead to understanding various scientific texts, the basics of science, as an exploration of our world and our senses, actually translates into skills necessary for reading and math understanding, comprehension, and analysis. Using observation and prior knowledge to create understanding, make predictions, and draw conclusions are at the heart of literacy and reasoning.

By integrating more science into other subjects and teaching students how to ask questions and seek knowledge on their own, this unit seeks to create scientifically-literate students who can see the links to scientific concepts in their daily life and in all of the subjects taught, realizing that science is not something you "do" during "science time" but a constant part of life.

An understanding of scientific method and observation can lead to students who are better problem solvers, with advanced comprehension skills and the ability to ask probing questions and explore abstract concepts. Contrary to the belief that students must have a deep understanding of math and high level vocabulary skills in order to understand science, children are scientists from the moment they begin to explore the world around them. Science is not a set of concepts, it is a process by which we create and understand our world. We begin with the simplest of all questions "what is this?" and "what's it for?" as babies. As we grow, it is up to our teachers to help u expand our understanding from "what does it do?" to "why does it do that?". This unit, while ostensibly about high level concepts of existence, creation, and the universe, is really about understanding how to observe and ask questions.

The National Science Standards put out by the National Science Teachers Association (NSTA) refer to the processes of science, whereby students learn observation, inference, and experimentation, and combine these processes with scientific knowledge and reasoning, and critical thinking skills to develop a true understanding of science. This inquiry approach to science allows students to develop an understanding of not only scientific concepts, but also the nature of science, and "how we know that". With the skills learned in early elementary inquiry, students do not have "facts" to remember or forget in the future, but a framework in which to build new understandings.[1]

Students are naturally predisposed to ask questions. Integrating units such as this one help the students to direct their questions and develop the skills of observation and modeling to think critically and logically about the answer to those questions.

Along with the skills for inquiry, students will begin to understand the ever changing, human-based aspects of science. By studying how great scientists throughout the years developed and established hypotheses and theories, and how those theories were tested, and sometimes thrown out, students will understand that our knowledge of science grows and changes and that it is a collaborative effort where each scientist builds on the work of others.

The focus of this unit, on understanding various systems that make up our existence, is a necessity to understanding the complexities of science. We cannot comprehend all of existence at one time, so we define "systems" of related objects to study. We start with simple systems, numbers, letters, words, and build to more advances and complex systems such as atomic structure, populations, ecosystems, genetics, and astronomy. Each system has a set of rules or laws that it must follow. When we study a system and begin to understand the laws that regulate that system, we can then apply that understanding to larger and larger systems, and make predictions about new systems, extending our knowledge outward so that we can develop an understanding of the universe, and our place in it.

By starting with simple systems, and understanding the laws and theories that apply to those systems, we can explain what we observe in the natural world. Understanding gravity and Newton's laws can lead us to a better understanding of the ways moons and planets stay in orbit, of how we stay on the Earth, and how we can be hurdling through space and yet feel like we are not moving.

We also learn to classify elements of a system with other like elements, allowing us to make comparisons, and understand relationships and interactions within the systems. These are skills students use in all curricular areas. In math students are asked to classify shapes and numbers, make comparisons, and understand the relationships between operations. In reading, students make connections between like elements of texts, understand the cause and effect relationships between events, and classify characters, events, and texts themselves to build comprehension.

In science, this classification allows us to understand how and why atoms exist the way they do, and interact with each other. By knowing the rules of attraction between positive and negative particles, and the stable configurations of atoms and molecules, we can see why some atoms react more readily with others.

Another important aspect of this unit is the use of modeling to visualize and observe different systems. By creating models of systems that are too big or too small to see, students are given a visual understanding of the concepts they are discussing, and can actually see how the elements interact. With ideas like atomic structure, where it is virtually impossible to actually "look" at a single atom, and the Universe, where all of the elements are so far away that they appear insignificantly small, or even invisible, a model gives the students a working idea of things they cannot actively see or touch. Astronomy is a difficult subject to teach in a concrete manner, since unlike Chemistry or Biology, we cannot observe closely and create experiments on the elements we are learning about. Modeling gives us a chance to interact with subject matter that otherwise would be out of reach.

Background pertinent to unit

What is a system? A system is a grouping of various related parts or things to create a whole that works together as a unit. All the members of a particular system are regulated by the same rules, laws, or procedures. Systems permeate our everyday lives, from atomic and molecular systems, to body systems, systems of government, and the Solar System are all examples of systems primary to our everyday life.[2]

Atoms

Atoms are the basic "building blocks" of all matter. All elements are made up of atoms – carbon, oxygen, helium, hydrogen, etc. Stars are made of mostly hydrogen and helium atoms. Planets, including Earth, comets, and asteroids, as well as water, air, plants, insects, animals, and humans are all made of different configurations of atoms.

An atom is defined as the smallest unit of an element, having all the characteristics of that element. It consists of a dense nucleus made of positively charged and non-charged particles, surrounded by a small, diffuse cloud of negatively charged particles called electrons. The number of protons and electrons in an atom are equal. Under normal circumstances, atoms cannot be broken down into smaller particles. The forces at work in the atom both attract and repel each other to hold the atom together as a unit.[3]

Where did these atoms come from? The creation of atomic nuclei is known as nucleosynthesis. Nuclei are created in two main kinds of nucleosynthesis, Big Bang nucleosynthesis (BBN) and stellar nucleosynthesis. In BBN, immediately after the "Big Bang" that is believed to have begun the universe, the universe was very hot and dense. As it expanded and cooled, it formed neutrons and protons, which interacted furiously until the universe had cooled too much for further nuclear reactions. Most of what remained as stable nuclei was then protons (hydrogen nuclei).

All other atoms that make up humans and everything around us were created through stellar nucleosynthesis, which is the creation of nuclei in a star. A star's energy to "shine" is the result of nuclear fusion reactions occurring in the core of the star, or the shell of the star. The end result of these reactions is that Hydrogen and Helium are fused to produce carbon, nitrogen, oxygen, and the iron group (iron, cobalt and nickel). When the star reaches its giant phase, much of this newly created matter is released into space, and someday may form into other matter, such as your body.[4]

New nuclei can also be created by collisions in space or Earth's atmosphere (called cosmic ray spallation, this process produces most of the lithium, beryllium and boron), or in a supernova. A supernova is an explosion that occurs when the core of a massive star has run out of fuel and has created iron and nickel. During the explosion, nuclei larger than nickel are formed by capturing neutrons, which produces most of the heavier elements, from copper to uranium, either directly or through the decay of heavier, unstable isotopes.[5]

Combinations and permutations

Combinations are all of the ways you can combine the same items to create different outcomes. In terms of the simplest combinations, this could be something like choosing clothes to wear, or choosing partners for group work. For simple combinations, where order does not matter, the number of outcomes is equal to the number of choices for each element. If you have 3 shirts and 2 pairs of pants, then you can make 3 x 2 or 6 unique outfits.

The same concepts work on a larger scale, such as in atomic structure. Different combinations of subatomic particles (protons, neutrons, and electrons) make the atoms of all of the different elements. Atoms can be anywhere from a single proton (Hydrogen) to 94 protons, 94 electrons and 150 neutrons (Plutonium). But atoms do not typically exist by themselves. They react with other atoms, changing and bonding to create molecules, such as water, Carbon Dioxide, and Sodium Chloride (table salt). The molecules can then interact in different ways to create more complex matter, from minerals to organisms. There are nearly infinite possibilities of combinations of subatomic particles into atoms, atoms into molecules, and molecules into complex structures.

If I have Hydrogen, which is a highly reactive atom, I can combine it with one or more Carbon molecules to create organic compounds, which can then also combine with Nitrogen, and Oxygen to create larger organic compounds. Hydrogen can also combine directly with Nitrogen or Oxygen to create molecules of Ammonia, water, or hydrogen peroxide. In this case we have 4 elements, Hydrogen, Carbon, Nitrogen and Oxygen, which can create molecules with 2 atoms, such as H_2, O_2, CO, OH, or with 3 atoms, such as H_2O, CO_2, and NO_2, or with 4 atoms such as H_2O_2 and NH_2, and so on to the complex organic chains that make up human and animal DNA (deoxyribonucleic acid) each base of which is made up of a sugar $C_5H_{10}O_4$ and one of four nucleotides $C_4N_3H_2O$ (cytosine), $C_6N_5H_8$ (Adenine), $C_5N_5H_5O$ (guanine) or $C_5N_2H_5O_2$. So a single base of the chain could have between 29 and 38 atoms, using just the 4 mentioned atoms. The human DNA chain has nearly 3 billion nucleotides, meaning over 100 billion atoms in each strand of DNA. [6]

The History of Astronomy – Myths, Theories and Models

Before humans had an understanding of the scientific basis of existence, the people of ancient civilizations observed the world around them and created stories to explain what they saw. Ancient Egyptian, Native American, Norse, and Greek civilizations each had their own set of myths to explain the creation of the universe, the rising and setting of the Sun, the patterns of stars in the sky, and the changing of seasons. Mythology was a means by which people could explain their observations using their prior knowledge and understanding.

Aristotle, Ptolemy and the Geocentric Model

Ancient Greek scientist-philosophers began to observe and make measurements of the heavens as early as 500 BC. Using systematic observations, mathematical and logical understanding and models they were able to deduce the shape and size of the Earth and the distances to the Moon and Sun. Without any tools to aid their observations, these astronomers were able to determine that the Earth is a sphere, and using the angle of the Sun calculated the Earth's circumference quite accurately. Early Greek astronomers noticed that while most stars remain in a fixed position relative to other stars, there were a few bright objects that moved relative to the other stars. They named these "planētai", the Greek word for wanderers, which in English are called planets.

The Early Greeks formulated a model of the universe with the Earth at its center, known as a geocentric model. This model was created based on the observations that everything in the sky seems to move from east to west, that the Earth is huge while all other celestial bodies are apparently much smaller, and that there is no apparent movement of the Earth. These models accurately explained the movement of the Sun, Moon, and stars through Earth's sky. They had a difficult time explaining the motion of the planets in this model, however. Not only do the planets move relative to the stars, but occasionally these "wanderers" would stop moving from west to east, as they typically did, and would instead move back toward the west, a condition called retrograde or backward motion. When the planets are in retrograde motion, not only do they change directions, but their path often bends, sometimes causing them to make loops in the sky.

The earliest known geocentric models were created by Greek astronomer Eudoxus, between 400-347 BC. In his model, the bodies that move fastest through the sky, the Moon and Mercury, are closest to the Earth, with Saturn the farthest known planet at the time. Eudoxus' model assumed that each body was mounted on two transparent spheres, one inside the other, tipped slightly with respect to one another. Later Greek astronomers Aristotle, Ptolemy, and many others created various more elaborate and complicated models to explain the motion of the planets and were able to make fairly accurate predictions.

Ptolemy (150 BC) was considered to be the greatest astronomer of his time and refined the models proposed by his predecessors to create a somewhat simpler model which allowed more accurate prediction. Ptolemy's model removed the spheres of Eudoxus and Aristotle, and instead has each planet travel in a small circle (known as an epicycle), which moved along a larger circle, with the planet's orbit as the center of the epicycle. This explained the motion of a planet from east to west as the rotation of the large cycle, and retrograde motion as caused by the epicycle moving the planet in the opposite direction.

Although Ptolemy's model predicted planetary motion with a fair degree of precision, there were still discrepancies with the true positions of the planets. Astronomers until the 1500s made modifications to Ptolemy's model which made it both more complex and more accurate. Finally, the failure of this model to make accurate predictions, along with its increasing complexity, finally led to its abandonment in favor of a much simpler and more accurate model.[7]

Copernicus, Galileo, Kepler and Newton – the Heliocentric Model

During the Renaissance period in Europe, scientists began to attempt to make sense of the centuries of data on planetary movement. A Polish physician named Nicolaus Copernicus came across a rejected idea from Aristotle's time, nearly 2000 years earlier, where a Greek named Aristarchus had first suggested a Sun-centered or heliocentric model for the Solar System. Copernicus developed a model where the planets orbit the Sun, creating a much simpler explanation for planetary motion, that the speeds of the planets in their orbits are such that a planet closer to the Sun will pass one farther away, causing the farther planet to appear to move backwards.

Although Copernicus' model was basically correct, it was met with hostility and skepticism since it was counter to the beliefs of the Catholic Church, and was no more accurate than Ptolemy's in predicting the positions of the planets. This was due to Copernicus' belief that the orbits of the planets are circles. Although this system was not accepted during Copernicus' lifetime, his system led to the accurate understanding of the Solar System developed in the following centuries.

Two Danish astronomers, Tycho Brahe and Johannes Kepler, working after Copernicus' death, were able to increase the accuracy of Copernicus' model. Brahe still believed that the Earth was central, but that all other planets orbited the Sun, which then orbited the Earth. Despite this, he designed and had made instruments that could make far more precise measurements of the positions of planets, and used his observations to show that stars and comets are not simply on a single sphere, but much further away than previously believed. His observations helped build an understanding of the cosmos as changing, and larger and more complex than previously believed.

Brahe's assistant, Kepler, used all of these observations and concepts to calculate that the planets do not move in circles, as Copernicus had suggested, but actually moved in an elongated shape known as an ellipse. He also discovered that the Sun was not at the center of the orbits, but actually off to one side at a focus of the ellipse. Using the new orbits, Kepler was able to make extremely accurate predictions of planetary positions.

At about the same time Brahe and Kepler were working, a new piece of technology, the telescope, was being developed which would allow astronomers to make more accurate observations. An Italian scientist named Galileo Galilei used this new invention to make amazing observations and discoveries, and to gather support for the heliocentric model. During the course of his observations, Galileo concluded that the Moon was a ball of rock, similar in many ways to the Earth, and that the Sun was rotating and changing from day to day, contrary to the beliefs that the Sun was perfect and unchanging.

Galileo is also credited with discovering 4 of the moons orbiting Jupiter, now known as Galilean satellites, proving that there were bodies in the heavens that did not orbit the Earth. He observed Saturn's rings, although his telescope was not advanced enough to see them as more than blobs around the planet's sphere, the phases of Venus, and the vastness of the Milky Way.

Galileo's firm support for the heliocentric system led him to be brought before the Inquisition and charged with heresy by the Catholic Church. He was placed under house arrest for the remainder of his life and it took 350 years before the Catholic Church admitted it had been wrong to condemn him for his ideas.

Further advances in technology, science, and understanding of the laws of motion and gravity, as developed by Sir Isaac Newton, all lead to a more refined and accurate model of the Solar System with the Sun as the central object, around which the planets revolve.[8]

Astronomical distances, comparative sizes of planets

Distances in space are so mind-bogglingly huge that we talk about distance in terms of the speed of light rather than our typical miles per hour or kilometers per hour, or even miles per second. Light travels at a speed of approximately 186,000 miles per second (300,000 kilometers per second); this is about 671 million miles per hour, or 10 million times the average highway speed limit. At this speed, light reflected off of the Moon takes only 1.3 seconds to reach Earth, and the light from the Sun, 93 million miles away, takes just over 8 minutes to arrive. If you were to drive that same distance, averaging 65 miles per hour, it would take around 163 years to get to our Sun.[9]

The closest star to Earth, besides our Sun, is Proxima Centauri. The light from this star takes 4 and a quarter years to arrive at Earth; to drive to that star would take 40,000 years! We express the distances to further space objects in light years. A light-year is the distance light travels in one year, around 9461 billion kilometers, or 5879 billion miles.

Within our own Solar System, distances are less mind-boggling, but still enormous. When talking about distances within our Solar System we use what is called an Astronomical Unit (AU) which is equivalent to the distance from the Earth to the Sun (about 93 million miles). Mercury is about 1/3 the distance from the Earth to the Sun, so it is said to be 1/3 AU from the Sun, or 2/3 AU from Earth. Pluto, on the other hand, averages about 40 AU from the Sun, making it about 40 times farther away than the Earth. Proxima Centauri, which we have already seen is a little over 4 light years away, would be 27,000 AU.[10]

While the distances in space are enormous, it is also important to understand the relative sizes of objects within our Solar System. If all of the mass of everything in our Solar System (the Sun, planets, moons, asteroids, etc) were put together, the Sun would make up over 99% of that mass. All of the other objects make up only 1% of the total mass of our Solar System. The dominance of the Sun, in terms of mass, helps to exert enough gravity to keep all of the other bodies in the Solar System in orbit around it. The next largest object, Jupiter, is about 10 times the diameter of Earth, and 300 times as massive.[11]

To think about the sizes of the objects in the Solar System, we can think of a scale model. In this model, the Sun would be 2.4 meters, or nearly 8 feet across. With the Sun this size, Jupiter, the second largest member of our Solar System, would be about the size of a basketball. Earth would be about the size of a large marble (a little under an inch in diameter), with Pluto being a tiny bead, about half a centimeter across, existing 6.3 miles away from our model Sun.[12]

Strategies

The main strategy for the bulk of this unit will be inquiry and questioning. The students will be responsible for coming up with questions based on the observations and discussions in class, and will follow their line of inquiry to discover answers, or to realize that answers to those questions are not available. In order to keep track of this questioning, the students will keep a journal of their observations, insights, and questions.

Another strategy used heavily in this unit is the use of interactive websites and multimedia presentations to learn about and explore concepts that do not lend themselves to other forms of hands-on inquiry. Many government sites hosted by NASA allow students to explore various aspects of space and science without needing to have access to equipment, or live in an area where nighttime observation is a possibility. Students will make observations of cycles through videos, and create scenarios that can be tested using the resources available through the internet.

We will use our understanding of place value and large numbers to study space in terms of mathematics. We will study sizes and distances in our Solar System, as well as talking about ratios, time for space travel, and statistics about various planets to make comparisons. We will use our geography skills to look at scales and create scale models of size and distance within our Solar System, and use NASA's Hubble website to understand distances in the galaxy and universe.

Continuing our mathematical study of these concepts, we will look at the possible combinations and permutations of atomic structure that make up all matter, and how the nearly infinite combinations account for the nearly infinite variety within the universe, and even just on our planet.

Students will use written, verbal, and artistic expression to record questions, thoughts, understanding, predictions, and new knowledge throughout the unit. There will be creative writing, such as creating new myths about what they observe in the sky, as well as scientific writing such as observation logs and lab summaries.

Once the students have explored and researched their various topics, they will then be responsible for a performance or presentation to teach their findings to their classmates. This will require a higher level of understanding in the students presenting, and will give the students in the audience a chance to learn from their peers and critique each other and themselves.

Classroom Activities

Activity 1: Atoms are everywhere

Use an atomic modeling kit, if available, otherwise subatomic particles can be represented by Styrofoam balls, clay, marshmallows, or other malleable "balls", connected by straws, toothpicks, pipe cleaners or other sticks. For best modeling, use different colors to represent each of the 3 subatomic particles – protons, neutrons, and electrons.

Begin by having the class brainstorm different types of matter (if needed, introduce matter and begin the brainstorm with simple ideas like water). Allow the class to come up with a good list, asking questions to lead to the inclusion of water, air, the Sun, plants, animals, people, etc. Set a time limit (~5 minutes) for the brainstorm. Discuss similarities and differences within the list. See if the students can come up with categories to classify the items on the list. What do all of the items have in common?

Explain that all matter is made of atoms, and all atoms are made of a nucleus, with protons and neutrons, which is surrounded by electrons. Have students work in groups of

2 or 3, starting with a single proton. This is primitive Hydrogen, formed during the Big Bang. Have them add an electron to model a typical Hydrogen atom. This is the simplest element in existence. Have the students sketch this atom in a notebook or journal. Repeat this modeling and sketching with the following elements (you may want to model Iron or draw a picture rather than having students model it):

Helium – 2 protons, 2 neutrons, 2 electrons
Oxygen – 8 protons, 8 neutrons, 8 electrons
Carbon – 6 protons, 6 neutrons, 6 electrons
Neon – 10 protons, 10 neutrons, 10 electrons
Iron – 26 protons, 30 neutrons, 26 electrons
Nitrogen – 7 protons, 7 neutrons, 7 electrons

Behind Hydrogen, these are the 6 most abundant elements in existence. Most matter is made of combinations of these 6 elements, with traces of others. Assign each group a common molecule, where the subscript number is the number of that atom in the molecule: N_2 (Nitrogen gas), O_2 (Oxygen gas), H_2O (Water), CO_2 (Carbon Dioxide), CO (Carbon Monoxide), O_3 (Ozone), H_2O_2 (Hydrogen Peroxide). Label each model and have students observe them. Discuss how they are similar and how they are different. They all have protons, electrons, and neutrons, but different numbers and combinations of each.

Atoms are examples of a system. All of the parts of the atom are bound by the same rules and laws, and will behave in accordance with those laws. The subatomic particles themselves are not considered to be units; they are the parts of the atomic system. The system can expand to include more subatomic particles, creating larger atoms, molecules, and compounds, but the parts of the system and the rules that bind it never change.

Put 3 containers on a table for students to observe – one empty (air), one with ice cubes or a block of ice, and the third with a piece of dry ice. Tell students that using only their sense of sight, they should observe and take notes on the 3 dishes. Make sure they do not touch any of the bowls. Help them to observe the characteristics of the contents of each bowl.

Discuss what is in each bowl – air (mostly Nitrogen and Oxygen), ice (H_2O), and dry ice (CO_2). Remind students of the models of these molecules. Did the models lead them to believe that they would behave so differently? Why are they so different if they are so similar? This is the basis for scientific knowledge – making observations, asking questions, and seeking answers that make sense based on current scientific knowledge.

Wrap up by referring back to the fact that everything is made up of those same 3 subatomic particles in many different combinations and configurations. That means the Earth, Sun, planets, moon, oceans, rocks, animals, people, furniture, and everything else are all made of the same stuff.

Activity 2: Observations, ancient explanations, and the Sun-centered Solar System

Ask students what they know about space, and write down some of the ideas they come up with. After a few minutes, ask them “how do you know that?” Discuss how we can know about the Sun and other planets if we can’t go measure them or touch them or study them like we can with plants and animals. Introduce the idea of observation and drawing conclusions.

Have students begin an observation journal in which they will observe the Sun, Moon, and stars without the aid of a telescope. Make sure to stress that they should never look directly at the Sun, but can chart its movement in other ways. Choose one of the cosmic cycles to have students observe daily over the course of a few weeks. This might be Sunrise and Sunset times or locations, moonrise and set times or locations, moon phases, what constellations are in the sky, or length of daylight hours. Students can observe these directly, or use various resources to gather the information, which they can then record and draw conclusions about. You may also facilitate this observation using computer resources, showing the students visuals that show the changes in these cycles over many nights, weeks, or months.

After making a number of observations, have students discuss what patterns they may have seen. Work toward an understanding that most bodies in the Solar System move from east to west during their cycles. Have the students try to work out an explanation for why everything in space seems to move, while we stay still. Introduce an Earth-centered model of the Solar System. Initiate discussion about what works or doesn’t work with our observations of cycles in the sky. Without being able to go out into space, or feel the Earth move, does this model make sense? Explain that this was the accepted model for nearly 2000 years.

Introduce astronomic observations, and astronomers such as Copernicus and Galileo, who used detailed observations to figure out that the above mentioned model does not quite fit the reality. By questioning the accepted “knowledge” of the time, and using careful observation and logic, these men were able to create a new model of the Solar System in which everything is moving and changing, although sometimes at rates much longer than the human lifespan. Work with students to develop a “new” model, starting with Ptolemy’s geocentric model, and changing to Brahe’s model, then finally to the modern heliocentric model. Discuss how the Solar System model is similar to the atomic models created previously. What part of the atom would the Sun be? What part of the atom would the planets be? Could there be other Solar Systems with different characteristics, like there are many different atoms? What laws would have to be in effect in those places like they are here?

Read the students some examples of myths that explain everyday occurrences, such as the rising and setting of the Sun. Have the students note how many of the explanations are quite similar, for example the Greek, Baltic, and Norse all believed a god drove a chariot, pulled by horses or goats, through the sky. The Egyptians believed it was a boat. They each also have their own explanation of how the Sun gets back to the East before Sunrise, whether it is taken by boat while the horses rest, or is taken through the underworld at night, making a full circle.

Another good example is myths that explain why we have different seasons. In Greek mythology, there is the story of Demeter and her daughter Persephone. Demeter is the goddess of the harvest, and when her daughter is kidnapped to the underworld, she goes into mourning and nothing will grow. She gets her daughter back, but only for a portion of the year, and every year when her daughter is away, she is sad and nothing grows, but when Persephone returns, Demeter rejoices and the world comes back to life. In Polynesia, Maui-of-a-thousand-tricks is believed to have snared the Sun with his sister's hair to slow it down, creating the longer summer days.

After reading a number of examples, have students choose an everyday occurrence, such as the Sun's movement through the sky, the Moon's phases, the stars or the seasons. Each student should then write a story that explains why that event happens the way it does. Have students share their stories and discuss the difference between a story and an explanation. What changed between the times of the ancient myths and the modern understanding of existence? Both were accepted as "fact" during their time, what makes one "science" and the other "story"?

Activity 3: Figuring Phases

Referring to the new heliocentric model the class has created, note that many planets have smaller bodies, called satellites or moons, which orbit the planet while the planet orbits the Sun. Talk about how each of these smaller systems follows the same rules as the larger Solar System. The Earth-Moon system is held together by gravity, orbits by the laws of motion, and involves cycles.

Each student will need a small Styrofoam ball, with one hemisphere (half) colored black and with a pencil, stick, or pipe cleaner stuck into the poles. This will represent the Moon, with the white side representing the side of the Moon that is being illuminated by the Sun, and the black side being the side that is not getting the Sun's light. Draw a picture of the Sun on the board, or put an object at the front of the room to represent it. Make sure students understand that the white side must always face the Sun. The student will represent the Earth.

It takes the Moon about one month to orbit the Earth. About every 4 days we see a new phase of the moon.

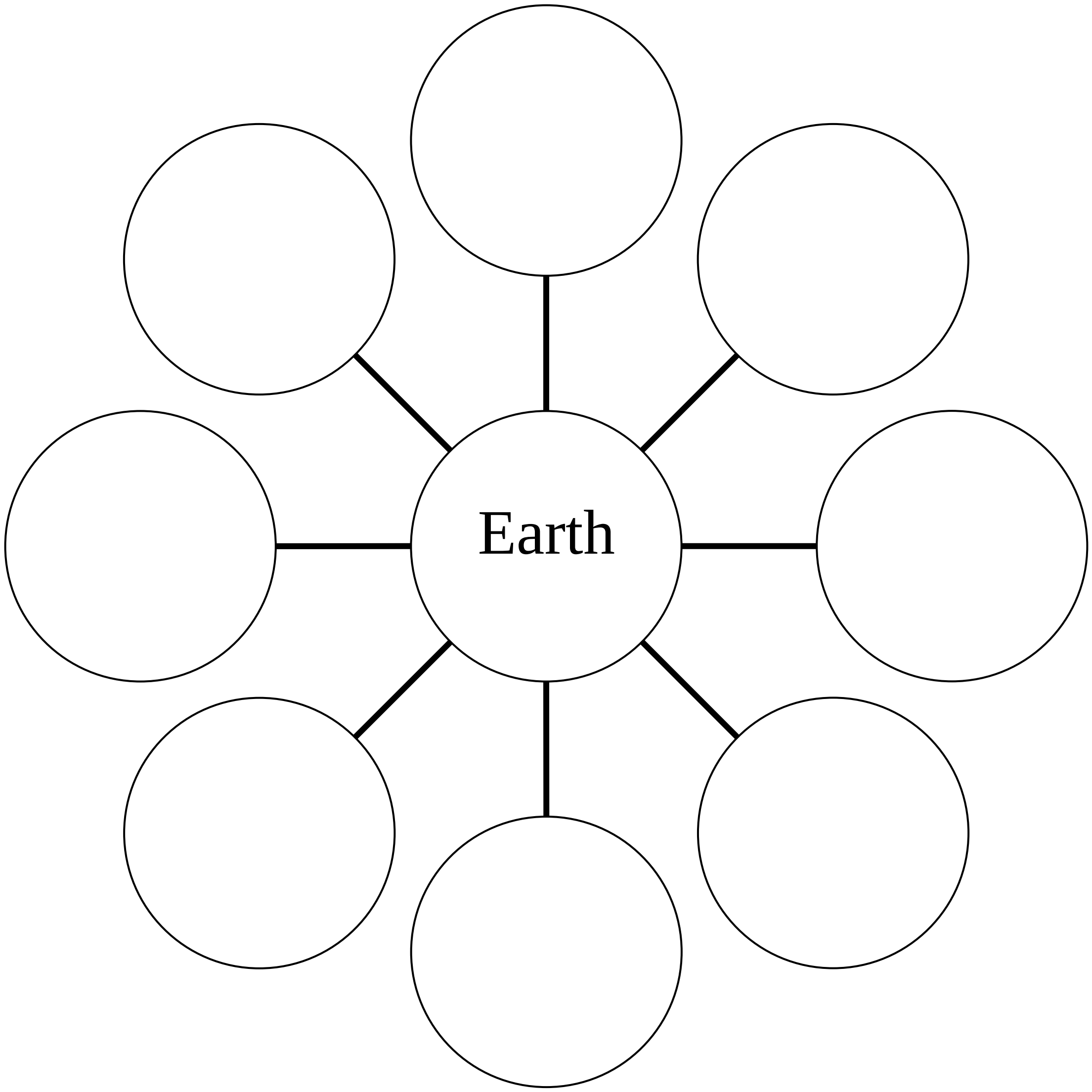
Have each student stand and hold the Moon out in front of them, facing the board, with the white side of the Moon also facing the board. Have them color in a Moon (figure 1) with what they see. They should fill in the circle completely, since all of the lighted side of the moon is facing away from them. This is called a “new moon” and we do not see any of the Moon at this phase.

Have the students turn 45° (to face the corner), keeping the white side of the moon facing the “Sun”. Have them record what they see. They should have all but a small portion of the face of the Moon colored. This is called a “crescent moon” because we see a crescent shaped portion of the Moon lit up.

Students continue to turn 45°, keeping the white side of the moon toward the board at all times, and recording their observations, until they return to the “new moon” phase. Help them to name the remaining phases – quarter moon, gibbous moon, full moon.

Discuss their findings. Questions for discussion may include “Does the moon actually change shape? Why does it look like it does?” “Is there a dark side of the moon?” “What patterns do you observe in the cycle of the moon’s phases?”

Figure 1 – Moon phases student worksheet – Each circle represents 1 phase of the moon



Notes

[1] "Science Content Standards"
[2] "Science Content Standards"
[3] Coffey, Jerry
[4] Tate, Jean
[5] NASA's Cosmicopia – Nucleosynthesis
[6] International Human Genome Sequencing Consortium
[7] Arny, Thomas, and Stephen E. Schneider
[8] Arny, Thomas, and Stephen E. Schneider
[9] NASA's Cosmicopia – Sun
[10] Dejoie, Joyce, and Elizabeth Truelove
[11] Arny, Thomas, and Stephen E. Schneider
[12] Martino, Bob

Resources

Teacher resources

Arny, Thomas, and Stephen E. Schneider. *Explorations: An Introduction to Astronomy.* 6th ed. Boston : McGraw-Hill, 2010.

An introductory Astronomy textbook. Written clearly and in terms a layman can understand, discusses all of the parts of our own Solar System, including how it likely formed, and many of the aspects of other galaxies. Easy to find information and very detailed.

Coffey, Jerry. "Atom Definition | Universe Today." Universe Today. http://www.universetoday.com/56347/atom-definition/ (accessed November 5, 2010).

A thorough definition of what is an atom, its size and makeup.

Comins, Neil F. *Discovering the Essential Universe* 3. ed. New York: W.H. Freeman, 2006.

A college level Astronomy textbook. Slightly more technical than “Explorations”, but with great photos and lots of graphs. Goes into more detail on the physics of space, including light waves and gravity.

Dejoie, Joyce, and Elizabeth Truelove. "Archive of Questions." StarChild: A Learning Center for Young Astronomers. http://starchild.gsfc.nasa.gov/docs/StarChild/questions/archive.html (accessed November 5, 2010).

A NASA-hosted archive of questions and answers to many frequently asked questions about space. Written by teachers for children of varying ages, with succinct but detailed explanations of everything space-related.

Hortert, Daniel. "ACE Cosmology and Stellar Evolution." NASA's Cosmicopia -- Home. http://helios.gsfc.nasa.gov/ed-acecosmo.html (accessed November 5, 2010).

Explanation of how scientists have studied the "Big Bang" and how nucleosynthesis started. Written for high school science teachers.

International Human Genome Sequencing Consortium. "Finishing the Euchromatic Sequence of the Human Genome." *Nature* 431 (2004): 931.

http://www.nature.com/nature/journal/v431/n7011/full/nature03001.html (accessed November 5, 2010).

A very technical article about the sequencing of the human genome, referenced for its information on the number of nucleotide bases in the human genome.

Martino, Bob. "Relative Size of the Planets." Perkins Observatory - Educational Resources. http://www.perkins-observatory.org/educational%20files/sizesofplanets.pdf (accessed November 5, 2010).

A good example of a way to model relative size and distance in the Solar System using easily obtained materials such as basket and soccer balls and marbles.

"NASA's Cosmicopia - Basics - Composition - Nucleosynthesis." NASA's Cosmicopia -- Home. http://helios.gsfc.nasa.gov/nucleo.html (accessed November 5, 2010).

NASA's brief explanation of nucleosynthesis, how atoms were formed.

"NASA's Cosmicopia -- Ask Us -- Earth and Moon." NASA's Cosmicopia -- Home. http://helios.gsfc.nasa.gov/qa_earth.html (accessed November 7, 2010).

Questions and answers about the Earth and Moon from NASA. A good resource for general information and frequently asked questions.

"NASA's Cosmicopia -- Ask Us -- Sun." NASA's Cosmicopia -- Home. http://helios.gsfc.nasa.gov/qa_Sun.html (accessed November 5, 2010).

A list of questions about the Sun with answers from renowned scientists. Includes how long it would take to drive to the Sun, and why we should not look directly at the Sun.

"Science Content Standards." In *National Science Education Standards: Observe, Interact, Change, Learn*. Washington, DC : National Academy Press, 1996. 103-208.

National standards for teaching science, includes rationale for inquiry-based science curricula and suggestions for teaching science concepts at all levels.

Tate, Jean. "Nucleosynthesis | Universe Today." Universe Today. http://www.universetoday.com/51797/nucleosynthesis/ (accessed November 5, 2010).

An explanation of how atomic particles were created in the big bang and

continue to be created through stellar (star) life-cycles. A bit technical, but fascinating.

Reading List for students

d'Aulaire, Ingri, and Edgar Parin d'Aulaire. *d'Aulaire's Book of Greek Myths*. [1st ed. Garden City, N.Y.: Doubleday, 1962.

An excellent and colorful book of Greek myths, including the formation of Earth, why the Sun moves through the sky, and many of the constellation myths.

Dejoie, Joyce, and Elizabeth Truelove. "StarChild: A Learning Center for Young Astronomers." StarChild: A Learning Center for Young Astronomers. http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html (accessed November 5, 2010).

A multi-leveled site for children to explore various stellar concepts, provided through NASA.

Goddesses, Heroes, and Shamans: The Young People's Guide to World Mythology. New York: Scholastic, 1994.

An interesting book summarizing the mythologies and important gods, goddesses and heroes from many different civilizations across all continents.

McDermott, Gerald. *Raven: A Trickster Tale From the Pacific Northwest*. San Diego: Harcourt Brace Jovanovich, 1993.

A short myth from a Native American tribe in the Pacific Northwest about how the trickster god Raven stole the Sun and placed it in the sky to give heat and light to humans.

Philip, Neil. *Mythology*. New York: Doling Kindersley, 1999.

Gives a broad overview of the different elements of Mythology, such as creation myths, the cosmos, etc, with some examples from various cultures.

Simon, Seymour. *Earth: our planet in space*. New York: Scholastic Inc., 2003.

Simon, Seymour. *The Moon*. New York: Scholastic, 2005.

Vogt, Gregory. *Earth*. Brookfield, Conn.: Millbrook Press, 1996.

Classroom materials

Atomic modeling kits, or a ball and stick system to model with, such as clay and toothpicks or marshmallows and straws
Observation journals
3 bowls
Ice cubes or a block of ice
A block of dry ice
Gloves and/or tongs to handle the dry ice
1 large Styrofoam ball
1 small Styrofoam ball per student, colored black on one hemisphere
Pipe cleaners