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Why Earth? A Study of Planetary Habitability

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Introduction

Have you ever looked at the stars at night? Of course, everyone has, but have you really seen them like I can see them in the New Mexico sky? We have over 300 days of sunshine a year, very few large population centers to create light pollution, and our high elevation reduces some of the interference of Earth's atmosphere; thus, we can see stars! When I moved to New Mexico in 1990, I was immediately drawn to the night sky. It wasn't a reaction of a science teacher; it was a feeling that is hard to describe. I felt wonder and awe; I felt relaxed and at peace; I felt alone yet not alone. New Mexico is a wonderful place for astronomers and stargazers. We have Sunspot, New Mexico where you will find the National Solar Observatory and nearby Apache Point Observatory. Down the mountains in Alamogordo is the New Mexico Museum of Space History. Further west is the National Radio Astronomy Observatory where at the Very Large Array (VLA) scientists "listen" for space conversation. That is also where many of the scenes in the movie *Contact* with actress Jodie Foster, a graduate of Yale, were filmed. We boast Clyde Tombaugh, the astronomer who discovered Pluto, and Alan Hale, who co-found the Hale/Bopp comet. The space shuttle landed once at White Sands Missile Range and the runway is still used as a backup/emergency landing site for current shuttle missions. Last, and definitely least, we have Roswell, home of the International UFO Museum and Research Center.

How could I not have at least some interest in Astronomy, and shouldn't my students have the opportunity to study about Astronomy and Space Science? The answer is yes, but what about Astronomy and Space Science is of interest to my students? What is relevant to my students? What do I know enough about to teach my students? Will this unit fit into my curriculum and if so, how?

Rationale

Making connections is critical for all students especially those in middle school. Students that age have difficulty focusing on school and question everything. So by asking the question "Why Earth", I aim to stimulate some interest, create connections, and make science relevant to my students. I teach Physical Science to at-risk students at a Title I middle school in Santa Fe, New Mexico. My school recently began a program called "looping", where the students stay with the same teacher for more than one year. So during the 2005-2006 school year, I will be teaching Seventh Grade Science, which has an emphasis on Life Science. The following year I will teach the same students Eighth Grade Science, which has an emphasis on Physical Science. If Seventh Grade is Life Science and Eighth Grade is Physical Science, what about Earth Science? Earth Science concepts are required to be taught both years in conjunction with Physical and Life Sciences. However, I admit, as do other teachers, that Earth Science topics, unfortunately, are often left out of our lessons as we concentrate on Life and Physical. As I was thinking how to develop the seventh grade curriculum based on Life Science with Earth Science as a supplement, I remembered our principal explaining that looping provides an opportunity to plan a curriculum over a two-year span as long as we teach all of the seventh and eighth grade standards sometime during the two years. So, since I had to begin fresh anyway, maybe if I found a topic of interest to my students, I could incorporate Life, Earth, and Physical Science. The opportunity to try came when I was accepted as a fellow with The Yale National Initiative. The science topic offered for the 2005 Seminars is titled *Astronomy and Space Sciences*. This subject could be a vehicle for integration. In college I took Science courses called Zoology, Botany, Chemistry, Physics, Geology all of which seemed very different and separate from each other. However, I remembered taking a class on Oceanography; and for the first time, science really came together for me and made sense. If the study of the ocean could combine sciences, could there be such a relationship for Space Science? The answer to that question is yes and can be described in one word, "Astrobiology"

Objectives

This unit will integrate Earth, Life, and Physical Science through the study of Astrobiology. It is intended for middle school students. Some basic math and measurement skills will be needed for the activities. Students will examine the reasons Earth has life and the other planets in our Solar System do not have life as we know it. They will identify the critical elements needed to sustain life and the factors that contribute to Earth's ability to support these plants, animals, and microorganisms. This unit will first examine definitions of life and then the factors that support this life. My students will create a "planetary shopping list".

Students will discover that life requires a supply of liquid water, a source of energy, and specific nutrients to survive. This will lead into studying how the Earth, its atmosphere, and the Sun provide these necessities. The New Mexico State Performance Standards that address these concepts are: "Explain why Earth is unique in our Solar System in its ability to support life" and "Explain how energy from the Sun supports life on Earth". By relating our lessons to the overarching question, "Why Earth", I hope to keep students' interest high and keep them focused.

Overview

Astrobiology

Astrobiology is the study of existing life and the potential for new life in the Universe, and is constantly changing as more information becomes available through a variety of scientific observations and experimentation. Astrobiology is a multidisciplinary science that includes Astronomy, Chemistry, Biology, Geology, and more. If you haven't heard of this field of science, it is not surprising since it has only been around since the mid 1990's. However, Astrobiology is actually just a new name for a NASA program previously titled "exobiology". In 1995 NASA changed the name and also the focus. The program was broadened to include more than biologists. astronomers, physicists, chemists, geologists, paleontologists, evolutionary molecular biologists, climatologists, and planetary scientists also were needed to answer questions about how habitable worlds form and evolve, is there life beyond Earth, and what is the future for Earth (1).

In 1998 the NASA Astrobiology Institute (NAI) was formed. The Institute focuses on finding planetary systems other than our own, looking for habitability within our own Solar System, studying Earth's early environment and how life evolved from simple to more complex forms. The NAI has 16 Lead Research Teams: NASA Ames Research Center, Carnegie Institution of Washington, Indiana University, Marine Biological Laboratory, Michigan State University, NASA Goddard Space Flight Center, Pennsylvania State University, SETI Institute, University of Arizona, University of California Berkeley, University of California Los Angeles, University of Colorado Boulder, University of Hawaii (Manoa), University of Rhode Island, University of Washington, and Virtual Planet Lab. The NAI also has international partners in Spain, Great Britain, Australia, and France. All of these entities conduct their own research but also collaborate with each other. NAI sponsors an Astrobiology Science Conference every two years where scientists share new findings (2).

NASA has developed an Astrobiology Roadmap as a long-range plan of action with the following seven goals (3):

- Understand the nature and distribution of habitable environments in the Universe
- Explore for past or present habitable environments, prebiotic chemistry and signs of life elsewhere in our Solar System.
- Understand how life emerges from cosmic and planetary precursors.
- Understand how past life on Earth interacted with its changing planetary and Solar System environment.
- Understand the evolutionary mechanisms and environmental limits of life.
- Understand the principles that will shape the future of life, both on Earth and beyond.
- Determine how to recognize signatures of life on other worlds and on early Earth.

One of the keys to implementing NASA's Astrobiology Program is public education. "The intrinsic public interest in astrobiology offers a crucial opportunity to educate and inspire the next generation of scientists, technologists, and informed citizens; thus a strong emphasis upon education and public outreach is essential" (3). There are many resources for students and teachers provided by NASA and many universities. The University of Arizona and Montana State University have developed lessons for grades 5-12 along with an on-line Astrobiology course for teachers. "From understanding how bacteria are able to live in extreme environments on Earth to searching for planets around other stars, the topics addressed in Astrobiology span nearly all fields of science" (4). These lessons are intended to supplement existing science curricula and are designed to take about 3 hours of class time to implement. A yearlong course for high school entitled "Astrobiology: An Integrated Science Approach" became available on July 1, 2005 from TERC. This course is advertised as a "truly integrated" approach, inquiry-based, hands-on, and low cost (5). Summer workshops in Astrobiology for teachers are available through Pennsylvania State University, University of Hawaii-Manoa, San Francisco State University, and the University of Nevada-Reno. Graduate programs in Astrobiology have also been developed at some universities including the University of Washington, and Montana State University offers a course for college level instructors to improve introductory Astrobiology courses for non-science majors.

Definition of Life

In order to look for signs of life on other planets, a working definition of life is useful. Some scientists refer to the book Beginnings of Cellular Life by Morowitz in which he describes 15 universal features of life (6). These indicators include the following:

- The cell is the most elementary unit that can sustain life.
- The cell has a membrane to separate it from other cells and the environment.
- Water content ranges from 50 to 90% and is needed for chemical reactions.
- Important elements are carbon, hydrogen, nitrogen, oxygen, phosphorus, sulfur.
- The non-aqueous portion is made of proteins, lipids, carbohydrates, nucleic acids.
- Genes are made of DNA and growing cells have ribosomes.
- Translation is through transfer RNA and reactions are catalyzed by enzymes.
- An ecological system is needed, not just a single organism or species.
- During replication alterations occur resulting in mutations in genes.

Of course, this definition points us in the direction of finding life, as we know it here on Earth. Astrobiologists are looking for very simple forms of life or even evidence of the ingredients that combine to form cells. Complex organic molecules are combinations of simple molecules; amino acids are the main components of proteins. These organic molecules can be formed from nonbiological processes as demonstrated by Stanley Miller and Harold Urey in 1952. They took gases that were made from the most common molecules in the Solar System and used an electric arc to simulate lightening. After a week, they had produced a substance that was made of amino acids (7 p. 682). Amino acids could have reached Earth from comets, asteroids, or even cosmic dust. However, how the amino acids could have formed into cells and developed into systems and then reproduced is not understood. Scientists are not just trying to detect the actual presence of life. They are also looking for places where life could exist.

Limiting Factors for Life

What are the critical elements needed to sustain life and what factors contribute to the Earth's ability to support these plants, animals, and microorganisms? Three basic requirements for life are a source of energy, a source of nutrients, and liquid water at or near the Earth's surface. A star is the energy source, meteorites and comets can be a source of minerals, and scientists are on the lookout for planets that have a reliable source of liquid water in their search for life beyond Earth. Earth's moderate temperature range is crucial to the existence of liquid water. Temperatures need to be between 0 degrees Celsius and 100 degrees Celsius for water to be in the liquid state. Fortunately for us this range in temperatures is quite large, so even with temperature variations between night and day and seasons, we can have liquid water. The traditional definition of habitability is "one on which liquid water is stable at the surface", and is based on the idea that life "will be carbon-based and will require liquid water" (8). Liquid water is often referred to as the universal solvent as many chemicals can be dissolved in it. Dissolved minerals are carried and delivered to living organisms by liquid water. Planets that can support life on their surfaces must be within the "liquid-water habitable zone (HZ)" (8).

Habitability is a function of the size of a planet, the distance of the planet to the Sun, the brightness of the Sun, the absorption and reflection energy balance of the planet, composition of its atmosphere, plate tectonics, presence of a magnetic field, gravitational interactions, protection from foreign objects, orbital and rotational dynamics, and more.

The Sun's Energy

As we know, our main source of all energy on Earth is from our star, the Sun. The basis of this energy is nuclear fusion where the nuclei of the simplest element, Hydrogen, fuse into the element Helium resulting in a great release of energy. The Sun is an example of what is called a Main Sequence star, which is very fortunate for us Earthlings. In order for life to evolve into anything more than primitive forms, a star needs to produce energy for at least 4 billion years, so stars need to be on the Main Sequence a minimum of 4 billion years. Scientists call the process of birth of a star to its death the life cycle of a star. Unlike humans who can choose from many paths to a career or even change careers during their lifetime, stars will progress along a predictable path based on their mass at birth. Our Sun started as a protostar, gas and dust that clumped together, and with time has become hotter and hotter and thus more luminous (luminosity is total energy output). This fusion of Hydrogen into Helium in the Sun will last about 12 billion years (7 p. 467). If our Sun had a greater mass, the fusion process would be much faster and thus use up the Hydrogen in just a few million years, which would be too short of a time period for life to evolve. If a star has a very low mass, it may never get hot enough to begin the fusion process, or if it did initiate a low level of nuclear "burning", the energy of the photon emitted would be much too low to trigger the formation of complex molecules necessary to develop life. So smaller stars may have enough time for complex life to develop but not enough energy.

Our Sun is only about halfway through its life cycle, but eventually it will convert all of the Hydrogen in its core to Helium. The core will then start to cool and shrink. This shrinking will result in gravitational energy changing into thermal energy, which will increase the temperature of the core. When the core is hot enough, the fusion of Helium into the heavier elements Carbon and Oxygen will begin. At this same time, the Sun's outside layers will push outward, the Sun will get brighter, and its atmosphere will grow large enough to "swallow" the inner planets. The Sun will then be classified as a red giant because even though the core will have increased in temperature, the surface temperature will have cooled and consequently will glow red. However, that's a long way off, about 7 billion years, so no need to lose sleep.

The Electromagnetic Spectrum

In order to understand more about the energy we receive from the Sun, we need to "look" at this radiation closer (Do not confuse the word radiation with radioactive materials like Uranium).However, we can only see one type of this radiation. Our eyes are sensitive only to the portion, which we call visible light. The entire range of radiation emitted from the Sun is called the electromagnetic spectrum. Although we may not be able to view the other types of radiation with our eyes, we are very familiar with the other forms; they are useful for communication, cooking, medicine, and more. We often refer to this electromagnetic radiation as light waves. If we think of light as waves, then we can talk about wavelengths and frequency. A wavelength is the distance between one point on a wave to the next similar point; it is often measured from crest (the top of the wave) to crest. The larger the distance from crest to crest, the longer the wavelength. Frequency is the number of waves you count that pass by in a certain amount of time, usually a second. If the waves are very long, not as many of them can pass by as when they are very short. Imagine you are watching a parade and are counting the floats. By the end of the parade, if the floats are short in length, the number you count will be large, but if the floats are long, the number you count will be small. So wavelength and frequency are inversely proportional, as one increases the other decreases. Radio waves have the longest wavelengths and gamma rays have the shortest. These longer wavelengths (lower frequency) have less energy than the shorter wavelengths (higher frequency).

Earth's Atmosphere

The shorter wavelength and higher frequency radiation is the type we need to be concerned about. I have never thought about protecting myself from radio waves. In fact, I invite them into my house, so I can listen to music or watch television. I do however put on sunscreen and wear sunglasses that assure me they block UVB and UVA rays, and I don't have too many x-rays in a year. But before the Sun's radiation reaches my sun-screened body, the Ozone in the stratosphere has already absorbed much of the ultraviolet radiation from the Sun. This energy, when absorbed by the Ozone molecules, breaks these O_3 molecules into regular O_2 molecules, thus preventing it from reaching the Earth's surface.

Planetary atmospheres also have an effect on the temperature of the planet's surface. Look at Venus for example. Being closer to the Sun than Earth, it receives more energy, so naturally it is hotter; however, the temperatures on Venus are much hotter than expected. This is due to the greenhouse effect. Because Venus has a dense atmosphere made up mostly of Carbon Dioxide, much of the Sun's radiation is trapped and heats the planet to temperatures way beyond the boiling point of water. On Earth, this same effect actually is beneficial. The Earth's atmosphere is not nearly as thick, so the temperature increase is not as drastic as Venus', but without the greenhouse effect, the Earth would be too cold, approximately 40 degrees Celsius colder (74 degrees Fahrenheit) (7 p.188). Earth's atmosphere is opaque to some wavelengths of light and transparent to others. It allows visible light to pass through but not infrared, just like the glass of a greenhouse allows the visible light to enter and warm the interior, but the lower energy infrared radiation radiated from the surfaces inside the greenhouse cannot escape.

This atmosphere that protects us has not been in place from the beginning of the planet, rather it developed from the releasing of gases through volcanic activity. The Carbon Dioxide escaped from volcanoes and volcanic vents creating the greenhouse warming of the Earth while also allowing the liquid water to produce water vapor that added to these protecting atmospheric layers. (7 p. 200) The early gases were very light and thus had enough energy to escape the gravitational pull of Earth. The larger Carbon Dioxide and water vapor molecules do not have the energy to meet the escape velocity. Small planets like Mercury are not massive enough to have the gravitational attraction to hold any atmosphere, and thus have no protective barrier. To retain an atmosphere, the mean velocity of the molecules in the atmosphere must be less than the escape velocity. The velocity of these particles increases with increasing temperature and decreases with increasing particle mass. The escape velocity increases as the mass of the planet increases, and it decreases as the radius increases.

Earth's Position and Motion

The distance from the Sun is the major determining factor for the amount of radiant energy the Earth receives. Mercury is too close to the Sun, and Mars is too far; Mercury receives too much of the Sun's energy and the planets beyond Earth receive too little. Like the story of the three bears, Mercury is too hot and Mars is too cold, but the Earth is just right. Actually, it's a little more complicated. A good portion of the Sun's energy does not get a chance to warm the surface as it is reflected back into space. White clouds, snow, and ice along with sand reflect about 39% of the sunlight; the portion of light a planet reflects is called its albedo. (7 p.188) In general, the surface temperature of the Earth does not fluctuate much, so the amount it actually absorbs equals the amount it radiates back. Luckily for us though, some of this energy emitted from the Earth's surface cannot escape and warms up the atmosphere and surface to an average temperature that supports life. To support life, a planet must be close enough to the star to be warm enough to allow liquid water but not so close that it will be so hot that this liquid water evaporates into a gas. This region is called the habitability zone or HZ or sometimes the life zone. As the lifetime of the star evolves, it gets hotter and produces more energy. This means the habitability zone will move outward from the star as this increasing energy can reach farther into the Solar System.

The Earth has two planetary motions that affect its habitability, rotation on its axis and revolution around the Sun. The Earth rotates once in approximately 24 hours resulting in what we call day and night. Without this motion, half of the Earth would always be dark and colder and the other half light and warmer, like the Moon. The shape of the orbit around the Sun also contributes to the habitability of our planet. Perturbation is the term astronomers use to describe how one object can cause changes in the path or orbit of another body in space. The eccentricity of the Earth's orbit is small, which means it does not have a great deal of variation in its orbit around the Sun. If the Earth had a more elliptical orbit, the other planets would influence it more, and the larger ones like Jupiter could have caused major disruption.

Earth's Magnetic Field

Another concern to the existence of Life on Earth is the solar wind. Solar wind is made up of high-energy protons and electrons that are emitted from the upper regions of the Sun and stream toward the Earth. Since protons and electrons are charged particles, protons being positively charged and electrons negatively charged, they can be deflected by a magnetic field. Living organisms on Earth are protected from the potentially lethal effects of the solar wind because Earth's magnetic field deflects the charged particles away from the Earth or toward the poles. When these particles are deflected toward the poles, the aurorae are produced.

You might picture the Earth with a big bar magnet in the middle; that is not an accurate representation. The magnetic field rather is due to the motion of the electrons in the iron-rich liquid core that generates the magnetic field. (7 p.197) If you place a compass near a magnet, the arrow will be influenced by the magnetic field. If you bring a compass near a wire carrying an electric current, you will see a similar reaction.

Size of the Earth

If the Earth were the size of the Moon, its interior would be solid with no molten material to produce a magnetic field or movement of plates of crust (plate tectonics). Any volcanic activity that might have existed would have stopped long ago. Without active volcanoes to produce the particles a protective atmosphere would not have been created. The gravitational pull would have been too small to hold in this atmosphere.

Planetary Shopping List

To summarize the criteria that scientists use when judging whether life could be found beyond Earth, we can put together a "planetary shopping list" to include the following:

- A main-sequence star that will provide enough energy but not too much and live long enough to allow life to develop.
- A planet that is close enough to the star to be warm enough to allow liquid water but not so close that it will be so hot that this liquid water evaporates into a gas.
- This region is called the habitability zone or HZ or sometimes the life zone.
- An atmosphere of enough Carbon Dioxide gas that allows the energy from the star to warm the surface

and trap some of this energy but not too thick that so much energy is trapped that again the liquid water evaporates.
- A planet that is large enough to generate enough energy to offset the loss of energy from the surface.
- An atmosphere that will absorb, reflect, or deflect the high-energy radiation.
- A magnetic field that will protect the planet from stellar wind.
- A safe distance from larger planets.
- An orbit with little eccentricity.

Strategies

My students are seventh graders who have just transitioned from the elementary to the middle school. In their elementary grades, they will have had some science content but little laboratory experience. Classes are 55 minutes long and meet everyday. The type of activities are limited as my room is not set up as a science lab; students share tables, there are two large sinks at the front of the room, no gas jets and no electrical plugs. However, having six computers in my classroom linked to the Internet will allow me to include interactive multimedia learning opportunities. Students will need to work in pairs on the computer; and since not all students will be able to use the computers at one time, students will be assigned another activity to complete when they are not using a computer. In a class of 24 students, I will have six groups with four students to a group. Each group will be assigned one of the computers and will need to coordinate within the group to decide which pair goes first. Once all four students in a group have completed the computer activity, that computer will be open to use by any pair of students who have not yet had the opportunity to get to a computer.

When teaching this unit, I also will use one of the foldable graphic organizers developed by Dinah Zike (see teachers' resource list). As the students study the electromagnetic spectrum, they will use the organizer to make notes, draw examples, list safety concerns, and compare the wavelengths, frequencies, and amount of energy for each type of radiation. While half of the students are organizing information using the foldable organizer, the other teams of students can logon to the interactive NASA Website *Amazing Space: Explorations Star Light Star Bright.* At this site, they will learn about waves and their properties, the electromagnetic spectrum, the relationship of color and temperature in stars including graphing temperature and peak wavelength. The site includes background information, quizzes, teaching tips, national science standards, and much more. The target audience is grades 6 through 9. The four activities and suggested time needed are "Catch the Waves" — 40 minutes "Making Waves" — 20 minutes "Heating Up" — 40 minutes "Stellar Encounters" — 40 minutes. To complete both the foldable organizer and website activities, four class periods will be required. If Internet connection is a problem, the teacher can order the CD or downloading the activity prior to class.

In an additional class period, I will introduce students to the ideal of life cycle of stars. Students need to understand that the type and age of a star will make a difference in the amount of energy released, which relates to the color of the star. The movie segments at the *BrainPOP* website could be viewed at individual computers or for the class as a whole. These videos are short, entertaining, and educational. Students will then create a life cycle diagram of stars using colored construction paper. If additional help is needed, students can ask questions using the NASA Website "Ask An Astrobiologist". The site has six categories where students can read through answers to previous questions, conduct a search using keywords, or post a new question.

As an enrichment activity for this unit, students will solve a "Space Mystery" titled *Alien Bandstand* involving a mysterious musical signal from outer space. This activity explores the age-old question of whether life exists beyond Earth. Students will investigate, collect and analyze information, and make logical conclusions. This site includes background information on waves; the electromagnetic spectrum; aurorae; stellar life cycle; optical, radio, and x-ray telescopes, black holes, supernovae, and more. Students cannot just guess; they keep notes in an online notebook and must pass a test in order to solve the mystery. Their results can be saved, so this activity can be extended beyond one class period. The teachers' guide includes information on system requirements, objectives, guide to solving the mystery, and worksheets. If the Internet is not available, there is a CD version also. This site also includes two other Space Mysteries, one about whether stars are really moving and the other investigates why a group of companies is buying certain types of stars. The *Alien Bandstand* activity better supports this unit, but if time permits, advanced students could explore the other two investigations.

Along with the computer activities, students will also participate in hands-on explorations. These activities use basic equipment and can be done in a regular classroom setting. There will be opportunities to incorporate measurement skills and mathematical calculations. The unit will take approximately 3 weeks to complete with 5 days for the computer activities described above and 10 days for the hands-on activities described below.

Lesson Plans

Three of the following activities are based on a NASA Educator Resource Guide titled "*Astrobiology in your classroom Life on Earth . . And elsewhere*?" The Resource Guide contains 5 classroom activities for grades 5-10 and can be downloaded in PDF form from NASA. I will use Activity One, *What is life?*, Activity Two, *What does life need to live?*, and Activity Three, *What makes a world habitable? T*wo hands-on activities *Radiation Measurements* and *Effect of Distance on Intensity of Light* will help students understand concepts needed for the last activity to determine what makes a planet habitable. NASA Activities Four and Five could be used as enrichment activities.

What is life?

Objective

To develop a working definition of life.

Materials

For each pair of students: a copy of *Activity Guide* for Activity One, a different pair of objects (i.e. live ant and plastic ant) for each pair of students, hand lens. For each group of four students: three jars, hot tap water in a container, 3 tbsp. sand per jar, 1 tsp. sugar per jar, half of ¼ oz. packet dry yeast for jar 2, 1 fizzing antacid tablet, crushed for jar 3, a copy of *Think About It* for Activity One.

Description

Students compare living and nonliving examples and develop their own working definition of life. The teacher background information lists characteristics that most living creatures share. The procedure suggests having one pair of objects for each student and lists 8 sets of suggested objects. For my classroom, I will need to have students work in pairs and will also need to increase the number of objects from 8 to 14 for classes up to 28 students. After the pairs of students have recorded their observations on the Activity Guide that is included in the Educator Resource Guide, students form groups of 4 students, compare the two lists, and create a new list with a common set of characteristics to use to identify life.

Students next test their definitions by playing a modified game of "20 Questions". I will first model the game with the class helping students form yes/no questions. The number of questions will be reduced to between 5 and 10. The Educator Resource Guide suggests some objects to use when modeling the game that should really help students to refine their original lists. Each group of 4 students will then think of an object for the rest of the class to question and subsequently guess the identity. These activities will take one class period.

The next class period each group of 4 students will observe, using a hand lens, three jars (sand and sugar; sand, sugar, and yeast; sand, sugar, and an antacid tablet). They can smell, touch, and listen but not taste. Students will then add hot water and make and record new observations. Each group will report to the class their findings and record their information on a class chart. The class will create a new working definition of life and students will complete the questions on the Activity Guide. The teachers' guide also includes a sheet of "Think About It" questions for use as a reflection on the activity. The suggestion is to use this sheet as an evaluation tool or for homework. I will use it for in class assessment and allow students to work together.

What does life need to live?

Objective

To establish the fact that all life requires water, nutrients, and energy to live.

Materials

For each group of students: a copy of *Activity Guide* (p. 16 & 17) for Activity Two, a copy of *How to tell what's growing in your environment* (p. 19) for Activity Two, a different *Environment Card* (p. 15), material for each of the twelve environments (see p. 14), hand lens and/or microscope.

Description

This activity will probably take two class periods for the set up and to complete the *Activity Guide* questions and another full day at the end of the activity to complete the *Think About It* questions. Since there are 12 environment cards and set ups, students groups will consist of 2 to 3 students depending on the number of students in each class. Student groups will think about, discuss with each other, and then create a list of what is needed for an organism to live a long time. Then each group will select at random one of the 12 environment cards. Students will then write a set of instructions (5 to 10 steps) to maintain this environment for 10 days in order for the organism to live. After getting approval of their plan from the teacher, students will prepare the environment following their plan. During the observation time, students will record their observations each day when they first come into the classroom. Students will include a drawing with their daily observations. The guide sheet will help students identify what is growing. At the end of the activity, students will answer the *Think About It* questions. During the ten-day observation period, students will complete activities on *What makes a world habitable?*

Radiation Measurements

Objective

To measure and compare the energy reflected and absorbed by different colored objects.

Materials

Per group: Styrofoam cup, 2 thermometers, data table, mirror, and ruler

Steps

1. Construct a simple radiant energy collector by making a hole in the center of the bottom of the cup using a pencil that is about the same diameter as the thermometer. Push the thermometer through the hole so that the bulb part is inside the cup 1 to 2 inches.
2. Take the students outside on a sunny day and have them measure temperature for a number of objects of different colors, including at least one dark and one light object. For each object, the students should measure both the temperature at the surface using the plain thermometer and above the object using the thermometer in the cup.
3. Students should also measure the temperature above the mirror and directly on the mirror.
4. Students should be sure to hold the radiant energy collector the same distance above all objects.
5. All measurements should be recorded in a data table.
6. Students will analyze data and based on their temperature data determine which colors absorb more energy and which reflect more energy.

Effect of Distance on Intensity of Light

Objective

To illustrate how The Inverse Square Law applies to intensity of light as distance changes. As the energy from a point light source radiates out, its intensity diminishes rapidly. Students will use the inverse square law to understand this relationship.

Materials

3 sheets graph paper, a ruler, and 1 flashlight per group

Steps

- 1. Label one sheet of graph paper Earth, one as Mercury, and one as Mars.
- 2. One student holds the flashlight 6 inches above the graph paper labeled Mercury.
- 3. The other student draws a circle around the brightest circle on light on the paper.
- 4. Students repeat the same procedure using 12 inches for Earth and 24 inches for Mars.
- 5. Students then count the number of squares enclosed by the circles. Students will have to estimate ½ or ¼ of a square for those partially enclosed squares depending on the size of the square on the graph paper. As an alternative, students can count all squares that have some light shining on them based on the assumption that these partially lit squares will average out.
- 6. Students will then calculate the energy per square. As all three graphs have the same intensity of light shining on them from the same flashlight, an assigned number for this energy can be used. The amount of power can be calculated by multiplying current times voltage. The flashlight bulb should indicate current in amperes (amps) and voltage in volts (v). Example is 0.7 amps. X 2.4 v = 1.7 watts. If you use two new 1.5 volts batteries in series the voltage should be 3.0 volts, so you could use either number for voltage.

Math Extension

The NASA Educator Research Guide Activity 3 Math Extension describes a class demonstration activity using an overhead projector that should help students understand the results from their experiment. Even though the projector is not a point source it still demonstrates the inverse square law fairly well. The intensity of the light energy changes in a predictable way as the light spreads out. At too great a distance from the Sun, the amount of energy is so reduced that the planet does not receive enough energy. The teacher shines the projector on a blackboard or whiteboard, students trace the lighted area on the board, measure the length of one side of the lighted square, and measure the distance from the light source to the board. The length of one side is squared to get the area of the lighted square. Students record their data in a data table. The distance of the projector to the board is subsequently doubled and then tripled. Students will make predictions first, collect new data, and record. Students will graph their data to see the trend and make further predictions based on their graph.

What makes a world habitable?

Objective

To assess the possibility of life in the Solar System.

Materials

For each group of four students: One set of *Habitability Cards*, *A Key of habitability factors* (p. 35) reference sheet, and *Searching for a habitable world* (p. 36) data chart.

Description

With background from the computer activities and the hands-on activities previously described, students should be prepared to compare other planets to Earth to determine if they could support life. Students will use *Habitability Cards* with facts about each of the planets and some of the moons of our Solar System along with *A Key of habitability factors* reference sheet to assess whether each planet or moon is a possible candidate for life or not. This activity uses the key habitability factors of temperature, water, atmosphere, energy, and nutrients. On the data chart, students will checkmark whether life is likely, life is possible, or if life is unlikely and state their rationale for their choice. After each group has completed the chart, the group will select its top 3 candidates and record their choices on a class chart and explain their reasoning to the whole class.

Notes

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(1) E. M. Goolish, *Astrobiology* **1**, 292 (2001).

(2) D. J. Des Marais *et al*., *Astrobiology* 3, 210 (2003).

(3) NASA Astrobiology Institute http://nai.arc.nasa.gov

(4) E. E. Prather, T. F. Slater, *Astrobiology* **2**, 215 (2002).

(5) TERC Astrobiology An Integrated Science Approach http://astrobio.terc.edu

(6) D. J. Des Marais, W. M. R. Walter, *Annual Review of Ecology and Systematics* **30**, 397 (1999).

(7) R. A. Freedman, *Universe* (Freeman, New York, ed. 7, 2005).

(8) J. F. Kasting, D. Catling, *Annual Review of Astronomy and Astrophysics* **41**, 429 (2003).

Resources for Teachers

Discovery Communication, Inc., *Discovery Schools* http://school.discovery.com Curriculum center for teachers with teaching tools, lesson plans, and information on Discovery programs; also resources and activities for students.

Gaidos, E. *et al.* "Beyond the Principle of Plentitude: A Review of Terrestrial Planet Habitability. *Astrobiology* **5**, 100-126 (2005). A current journal article that reviews recent work on habitability of terrestrial planets like the Earth.

Liebert, Mary Ann http://www.liebertonline.com Index to citations of articles on Astrobiology in professional journals.

Matsos, Helen, Chief Editor http://www.astrobio.net *Astrobiology Magazine: Search for Life in the Universe* Affiliated with NASA's Ames Research Center. Articles, information, and discussion groups for the "Astrobiology Community".

NASA Ames Research Center http://abscicon.arc.nasa.gov *Astrobiology Science Conference*; past and future conference information.

NASA Ames Research Center http://astrobiology.arc.nasa.gov/roadmap/index.html Complete text of *The NASA Astrobiology Roadmap* composed of 7 goals; final version September 2003.

NASA Ames Research Center http://astroventure.arc.nasa.gov/teachers/teach.html *Astroventure* Teacher and Parent links, resources, and educator guide. Students in grades 5-8 role-play, search for, and build a planet for human habitation.

NASA Astrobiology Institute http://nai.arc.nasa.gov Website gives background information on NAI, links users to NASA sites for teachers and students, and links users to "Ask an Astrobiologist", to newsletters, to events, and to NAI partners.

NASA Central Operation of Resources for Educators (CORE) http://education.nasa.gov/edprograms/core/home/index.html The worldwide distribution center for NASA-produced multimedia materials; educators may purchase materials for a minimal charge.

NASA Education http://www.education.nasa.gov/home/index.html NASA Education homepage.

NASAexplores http://nasaexplores.nasa.gov Express Lessons and Online Resources.

NASA Johnson Space Center Institute for the Study of Biomarkers in Astromaterials http://ares.jsc.nasa.gov/Education/Websites/AstrobiologyEducation/index.html *Fingerprints of Life Classroom Activities* include "Searching for Life", "Extremophiles", "Classification", and more using slide shows and PDF files.

NASA Space Mysteries http://www.nasa.gov/audience/foreducators/5-8/features/F_Space_Mysteries.html Teacher resources for Space Mysteries curriculum.

National Science Teachers Association (NSTA) *The Science Teacher* February 2005 Volume 72. Focus is on "Our Place in the

Universe" Includes CD *Cosmic Evolution from Big Bang to Humankind*.

National Teachers Enhancement Network http://www.Scienceteacher.org/courses/phys582.htm Online course for certified middle and high school teachers PHYS 582-01 ASTROBIOLOGY FOR TEACHERS.

Plait, Phil http://www.badastronomy.com Astronomer at Sonoma State University, California. Website explains misconceptions and misuse of astronomy including popular movies http://www.badastronomy.com/bad/movies/index.html#list

SETI Institute (Search for Extraterrestrial Intelligence) http://www.seti.org Private, nonprofit organization to explore, understand and explain life in the universe. Astrobiology Summer Science Experience for Teachers (ASSET), a science and curriculum institute for high school science teachers. Voyages Through Time curriculum for high school, Life in the Universe Teaching Guides, and more.

TERC Astrobiology An Integrated Science Approach http://astrobio.terc.edu a full-year, inquiry-based, integrated science high school curriculum offered from TERC.

TERC http://nai.arc.nasa.gov/library/downloads/ERG.pdf Downloadable Educator Resource Guide for *Astrobiology in your classroom Life on Earth . . . and elsewhere?* Hands-on activities for Grades 5 ñ 10 including instructions and student worksheets.

UCLA Center for Astrobiology http://astrobiology.ucla.edu Focus is on Extrasolar Planetary Systems, Habitability within the Solar System, Earth's Early Environment and Life, and Evolution of Biological Complexity.

WGBH Educational Foundation NOVA *Origins* http://www.pbs.org/wgbh/nova/origins Four-part NOVA miniseries originally aired 2004 (repeated 2005) "Journey back to the beginning of everything, the universe, Earth, and life itself." Teachers can use for up to one year after taping; downloadable 8-page Teacher's Guide with student handouts. Students can access slide shows, interviews, and more at website.

Zike, Dinah http://www.dinah.com Dinah Zike is know for her three-dimensional, educational manipulatives that help students "organize, display, and arrange data".

Resources for Students

Amazing Space NASA Space Telescope Science Institute's Office of Public Outreach http://amazing-space.stsci.edu "Uses Hubble Space Telescope's discoveries to inspire and educate about the wonders of our universe"

Ask an Astrobiologist? NASA Astrobiology Institute (NAI), http://nai.arc.nasa.gov/astrobio/index.cfm Reference for students/teachers.

Astroventure NASA Ames Research Center http://astroventure.arc.nasa.gov/avhome.html "Search for an design a habitable planet!"

BrainPOP http://yahooligans.yahoo.com/content/Science/space/index.html Animated, educational K-8 movies on Life Cycle of Stars, Solar System, Sun, Moon and more.

Origins Exploratorium, http://www.exploratorium.edu/origins "Search for the origins of matter, the universe, and life itself"

Imagine the Universe NASA's High Energy Astrophysics Science Archive Research Center () Goddard's Space Flight Center http://imagine.gsfc.nasa.gov/docs/homepage.html webpage for 14 years old and up.

Star Central Astrobiology Institute, Marine Biological Laboratory http://starcentral.mbl.edu/mv5d Website has images of microbes, classification schemes, descriptions of organisms.

Star Child A Learning Center for Young Astronomers NASA) http://starchild.gsfc.nasa.gov/docs/StarChild/StarChild.html

Space Mysteries Sonoma State University funded by NASA LEARNERS program http://mystery.sonoma.edu/index.html Three interactive activities for grades 5-8.