Astro-Venture: Astronomy Educator Guide

An Educator Guide with Activities in Astronomy and Astrobiology

http://astroventure.arc.nasa.gov
Astro-Venture: Astronomy Educator Guide is available in electronic format through NASA Spacelink--one of NASA’s electronic resources specifically developed for the educational community.

This publication and other educational products may be accessed at the following address:

http://spacelink.nasa.gov/products
# Table of Contents

**Introduction/Overview/Goal/Objectives** ................................................................. 7  
Astro-Venture Concept Map ..................................................................................... 10  
Astro-Venture Astronomy Lessons, Objectives and Standards Alignment .............. 12  
Educational Standards List ..................................................................................... 21  

**Part 1: Unit Introduction** .................................................................................... 26  
**Lesson 1: Unit Introduction** ............................................................................... 27  
  Astro-Venture Academy Acceptance Letter ......................................................... 34  
  Astro-Venture Academy Materials Packet ............................................................ 35  
  Astro-Venture Career Fact Sheets ...................................................................... 37  
  Astro Journal Lesson 1: Unit Introduction ............................................................ 44  
  Human Requirements Reading ............................................................................ 46  
  Survival Story ...................................................................................................... 48  
  Planetary Comparison Chart ............................................................................. 49  

**Lesson 2: Astronomy Training Module** ............................................................. 50  
  Astro Journal Lesson 2: Astronomy Training Module ......................................... 56  
  Astronomy Training Walkthrough ..................................................................... 58  
  Astronomy Training Module Screen Shots ......................................................... 60  
  Planetary Comparison Chart ............................................................................. 72  

**Generic Astro Journal** ................................................................................... 73  
**Scientific Inquiry Evaluation Rubric for Evaluating Astro Journal Entries** ........ 75  

**Part 2: States of Matter** ...................................................................................... 76  
**Lesson 3: Properties of Matter** ....................................................................... 77  
  Astro Journal Lesson 3: Properties of Matter ................................................... 83  

**Lesson 4: Matter and Molecules** .................................................................... 85  
  Astro Journal Lesson 4: Molecules and Matter .................................................. 91  
  Activity: Storing and Transporting Matter ......................................................... 93  
  Assignment: Molecules and Matter Poster ....................................................... 94  

**Lesson 5: Changing States of Matter** ............................................................... 95  
  Astro Journal Lesson 5: Changing States of Matter ......................................... 102  
  States of Matter Test ......................................................................................... 104  

**Lesson 6: Measuring Temperature** ................................................................. 106  
  Astro Journal Lesson 6: Measuring Temperature ............................................... 112  
  Measuring Temperature Reading ..................................................................... 114  

**Generic Astro Journal** ................................................................................... 116  
**Scientific Inquiry Evaluation Rubric for Evaluating Astro Journal Entries** ........ 118  

**Part 3: Astronomical Factors** ........................................................................... 119  
**Lesson 7: Thinking in Systems** ................................................................. 120  
  Astro Journal Lesson 7: Thinking in Systems .................................................... 128
Acknowledgements

Christina O’Guinn
Instructional Designer

Mike Wendling & Christina O’Guinn
Curriculum Specialists

Amberlee Chaussee
Design and Layout

Mariana Triviso, Bonnie Samuelson, Dorthy Starr
Editors

Emma Bakes, Robbins Bell, Rita Briggs, Mitch Gordon
OSS Educational Product Review Committee, Scientific Review
Introduction
The Astro-Venture Astronomy Lessons have been developed by the National Aeronautics and Space Administration (NASA) for the purpose of increasing students’ awareness of and interest in astrobiology and the many career opportunities that utilize science, math and technology skills. The lessons are designed for educators to use with students in grades 5-8 in conjunction with the Astro-Venture multimedia modules on the Astro-Venture Web site <http://astroventure.arc.nasa.gov>.

Astro-Venture Overview
Astro-Venture is an educational, interactive, multimedia Web environment highlighting NASA careers and astrobiology research in the areas of astronomy, geology, biology and atmospheric sciences. Students in grades 5-8 are transported to the future where they role-play NASA occupations and use scientific inquiry as they search for and build a planet with the necessary characteristics for human habitation. Supporting activities include chats and webcasts (live streaming audio and video) with NASA scientists, classroom lessons and NASA occupations fact sheets and trading cards.

Astro-Venture Overall Goal
Astro-Venture uses astrobiology content, the scientific inquiry process and critical thinking skills to increase awareness of NASA careers and to educate students in grades 5-8 on the requirements of a habitable planet.

Astro-Venture Overall Objectives
• Students in grades 5-8 will be able to identify and explain the vital characteristics of Earth which make it habitable to humans.

• Students will use the process of scientific inquiry to explain the methods scientists use to find planets that have characteristics necessary to sustain human life.

• Students will design a planet that has all of the necessary features to support human survival.

• Students will identify at least one NASA occupation that best fits their interests and skills and will identify methods for pursuing a similar career.

Astro-Venture Structure
Astro-Venture is composed of online, interactive, multimedia modules and off-line classroom lessons. The story line and technology components provide the overall purpose and motivation for teaching the standards and concepts in the off-line lessons. The technology components also help to connect students to real science and scientists at NASA.

Astro-Venture is divided into five sections or "Research Areas."
1. Astronomy
2. Geology
3. Atmospheric Sciences
4. Biology
5. Design a Planet
The first four sections have the following components:

**Training (The “Whats”)**
In each of these interactive, online, multimedia modules, students make changes to aspects of our Solar System and make observations of the effects on Earth. They then draw conclusions about the conditions that are required for human habitation in that science content area. In these training modules, students learn what humans need in a planet and star system to survive.

**Classroom Lessons (The “Whys”)**
Off-line, students engage in many classroom investigations in which they learn why humans need the requirements identified in the training modules. These lessons have been developed to meet national education standards and build on each other to truly teach standards-based concepts such as: states of matter, systems, the geologic rock cycle, human health systems and atmospheric composition.

**Missions (The “Hows”)**
After completing the training modules and lessons, students will engage in interactive, online, multimedia missions to simulate the methods scientists might use to search for a star system and planet that meet the qualifications identified in the training modules. In these modules, students learn how to go about finding a planet that would support human survival.

**Design a Planet (Overall Assessment)**
Once students have completed the first four sections, they will engage in the online, interactive, multimedia Design a Planet module in which they will design a simulated star system and planet that meets all human survival requirements in all four areas: astronomy, geology, atmospheric sciences and biology.

**Project 2061**
In addition to meeting the National Science Education Standards, International Society for Technology in Education Standards and National Council of Teachers on Mathematics standards, the Astro-Venture Astronomy Lessons are written to meet benchmarks from the *Benchmarks for Science Literacy* produced by the American Association for the Advancement of Science (AAAS) as part of their science, math and technology reform movement called Project 2061. The mission of Project 2061 is to "shape the future of education in America, a future in which all students [will] become literate in science, mathematics and technology by graduation from high school" (p. VII). "The Benchmarks for Science Literacy are statements of what all students should know or be able to do in science, mathematics and technology by the end of grades 2, 5, 8 and 12" (p. XI) and are based on extensive research of when and how it is developmentally appropriate to teach the concepts and skills described.

The table below shows how these benchmarks are identified for each lesson. There is a great deal of overlap between the *Benchmarks for Science Literacy* and the national science and math education standards. Therefore, we have also identified these standards, when appropriate. The first portion of the table entry identifies which standards or benchmarks are referenced. 2061 is a reference to the *Benchmarks for Science Literacy*. NSES is a reference to the National Science Education Standards. NCTM is a reference to the National Council of Teachers on Mathematics national mathematics education standards. ISTE is a reference to the International Society for Technology in Education standards. The second portion of the table entry identifies the specific standard referenced. In the case of Project 2061, the standard is referenced, the grade range is referenced and finally the number of the concept under this standard and grade range is referenced. We distinguish between "meeting" benchmarks or standards, and "addressing" them to alert educators to concepts that are taught in a lesson or lessons compared to topics or ideas that we might touch upon but do not really teach. Educators may note that often several lessons are required to truly teach a concept. We understand the time constraints of the classroom may not allow for the time that is really needed to truly teach a concept or benchmark; however, it is our goal to model effective instructional methods for science, math and technology. As stated in *Benchmarks for Science Literacy*, "If we want students to learn science, mathematics, and technology well, we must radically reduce the sheer amount of material now being covered" (p XI).
Example of Lesson Objectives/Standards Table

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will research and list the basic requirements for human survival</td>
<td>Meets: 2061: 6C 3-5 #1, 2</td>
</tr>
<tr>
<td>in their Astro Journals.</td>
<td>Addresses: 2061: 4B 6-8 #2</td>
</tr>
<tr>
<td>They will write a survival story identifying these basic requirements,</td>
<td></td>
</tr>
<tr>
<td>the consequences of not meeting them and how they are met.</td>
<td></td>
</tr>
<tr>
<td>After comparing characteristics of the Earth with other planets and</td>
<td></td>
</tr>
<tr>
<td>moons, students will predict which features of the Earth they believe are</td>
<td></td>
</tr>
<tr>
<td>crucial to human survival.</td>
<td></td>
</tr>
</tbody>
</table>

In addition to meeting benchmarks, the Astro-Venture Astronomy Lessons integrate some of the instructional methods that Project 2061 research has identified as being the most effective in teaching science, math and technology. These include:

- **Overall Purpose**: We provide an overall purpose or goal and connect to this throughout. We base measurable objectives and assessments, which evaluate these objectives on the overall purpose.
- **Prerequisite Knowledge/Skills/Misconceptions**: We identify prerequisite knowledge and common misconceptions. We alert educators to these misconceptions and provide questions or suggestions on how these might be addressed.
- **Variety of Phenomena/Quality of Experiences**: We provide a variety of highly interactive experiences and questioning strategies that require higher order thinking skills.
- **Introducing Terms**: We limit the use of terms and introduce them within context once the concept is understood.
- **Welcoming All Students**: We strive to make the content accessible to all student populations by providing suggestions for accommodations for students who might benefit from modifications and Advanced Extensions for students who can benefit from additional challenges. In addition, we incorporate cooperative learning, hands-on activities and total physical response activities to facilitate the learning of students who speak English as a second language and to address multiple learning styles.

**Astro-Venture Concept Map**

The following map (please see the following two pages) demonstrates the Benchmarks for Science Literacy and National Science Education Standards that have been identified for Astro-Venture. The map shows the overall concepts that are taught throughout Astro-Venture, as well as the benchmarks specific to the different sections. The map also shows the prerequisite benchmarks that students should have mastered prior to learning the benchmarks in Astro-Venture.

More information on the benchmarks and standards referenced can be found at the following Web addresses:

<table>
<thead>
<tr>
<th>Standard/Benchmark Title</th>
<th>Web Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>American Association for the Advancement of Science: Project</td>
<td><a href="http://www.project2061.org/">http://www.project2061.org/</a></td>
</tr>
<tr>
<td>2061</td>
<td></td>
</tr>
<tr>
<td>National Science Education Standards (NSES)</td>
<td><a href="http://www.nap.edu/readingroom/books/nses/html/">http://www.nap.edu/readingroom/books/nses/html/</a></td>
</tr>
<tr>
<td>National Council of Teachers on Mathematics (NCTM)</td>
<td><a href="http://standards.nctm.org/index.htm">http://standards.nctm.org/index.htm</a></td>
</tr>
<tr>
<td>International Society for Technology in Education (ISTE)</td>
<td><a href="http://cnets.iste.org/">http://cnets.iste.org/</a></td>
</tr>
<tr>
<td>International Technology Education Association (ITEA)</td>
<td><a href="http://www.iteawww.org/TAA/TAA.html">http://www.iteawww.org/TAA/TAA.html</a></td>
</tr>
</tbody>
</table>
Thinking about things as systems means looking for how every part relates to others. The output from one part of a system can become the input to other parts. Any system is usually connected to other systems. Atoms and molecules are perpetually in motion. Increased temperature means greater average energy of motion, so most substances expand when heated. In solids, the atoms are closely locked in position and can only vibrate. In liquids, the atoms or molecules are more loosely connected, and can slide past one another. In gases, the atoms or molecules have still more energy and are free of one another. NSES: B 5-8 #12 Substances react chemically in characteristic ways with other substances to form new substances with different characteristic properties. In chemical reactions, the total mass is conserved. Substances are often placed in categories if they react in similar ways. All matter is made up of atoms. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules. The earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the earth's. The earth's force of gravity enables the planet to retain an adequate atmosphere. The solid earth is layered with a lithosphere; hot, convecting mantle, and dense metallic core. The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere. Plants alter the earth's atmosphere by removing carbon dioxide, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air. If the atmosphere does not have enough ozone, solar radiation will damage plants and animals. Ozone in our atmosphere protects humans from radiation. Earth's atmosphere also has low levels of poisonous gases. In addition, Earth's atmosphere has the right level of "greenhouse" gases to make the temperature habitable for humans. Our atmosphere provides the necessary amount of pressure and interacts with our bodies to help us gain proteins and energy. Food provides molecules that serve as fuel and building material for all organisms. Plants use the energy in light to make sugars out of carbon dioxide and water. This food can be used immediately for fuel or molecules or it may be stored for later use. Organisms that eat plants break down plant structures to produce the materials and energy they need to survive. Then they are consumed by other organisms. Humans need: water, oxygen, food, gravity, moderate temperature, low levels of poisonous gases, and protection from solar flares and high levels of radiation to survive.
**Astro-Venture Astronomy Section**

In the Astronomy section, students begin as Junior Astronomers where they identify human needs for survival and complete the online Astronomy Training module to discover the astronomical conditions of our Solar System that make Earth habitable to humans. When they have successfully completed their training, they earn their badge and are promoted to Senior Astronomer. They then engage in off-line Astronomy lessons to discover why we need the astronomical conditions identified in Astronomy Training. Finally, they proceed to their online Astronomy Mission where they work with NASA scientists to find a star system and planet with the astronomy features that will support human life. Before embarking on further research in other areas, they must summarize their research findings and convince the World Science Foundation (a fictional group made up of their peers) that the planet they have found is worthy of further exploration.

The objective and standards of Astro-Venture Astronomy are broken down into fourteen lessons, as shown in the following table:

**Astro-Venture Astronomy Lessons, Objectives and Standards Alignment**

**Unit Concept:** For a planet to support human life, it must have liquid water at or near the surface all of the time. There are astronomical factors, which affect the ability of a planet to have these conditions.

**Part 1: Unit Introduction Lessons**

**Overview of Part 1:** Students are introduced to the basic requirements for human survival. Using an online, multimedia module, they change factors of our Solar System and draw conclusions about which factors are necessary for human survival.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Main Concept</th>
<th>Scientific Question</th>
<th>Objective</th>
<th>Benchmarks/Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Unit Introduction</td>
<td>Humans need water, oxygen, food, gravity, a moderate temperature and protection from poisonous gases and high levels of radiation to survive.</td>
<td>What do humans need to survive? Why?</td>
<td>Students will research and list the necessities for human survival in their Astro Journals.</td>
<td>Meets: 2061: 6C 3-5 #1, 2 NSES: F 5-8, #1 Addresses: 2061: 4B 6-8 #2 NSES: A 5-8 #1 ISTE: 3, 5</td>
</tr>
<tr>
<td>2. Astronomy Training Module</td>
<td>Certain astronomical conditions help to meet some of our human survival needs.</td>
<td>What astronomical conditions allow for human survival?</td>
<td>Students make descriptive, un-biased observations of the effects of changes to our solar system on Earth.</td>
<td>Meets: NSES: A 5-8 #1 ISTE: 3, 5 Addresses: 2061: 4B 6-8 #2 2061: 4A 6-8 #1 NSES: D 5-8 #3</td>
</tr>
</tbody>
</table>
**Part 2: States of Matter**

**Overview of Part 2:** Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Main Concept</th>
<th>Scientific Question</th>
<th>Objective</th>
<th>Benchmarks/Standards</th>
</tr>
</thead>
</table>
| 3. Properties of Matter | Matter can exist in three states: solid, liquid and gas. Each state has unique properties. | What are the similarities and differences between the properties of solids, liquids, and gases? | Students will identify the properties of solids, liquids and gases and will cite similarities and differences in those properties. | Meets: NSES: B K-4 #1  
Addresses: NSES: A 5-8 #1 |
| 4. Matter and Molecules | The properties of matter derive from the bonds between the molecules and the motion of the molecules that make up the matter. | Why do the states of matter have the properties that they have? | Students will explain and illustrate that the properties of matter derive from the connections between molecules.  
They will demonstrate their learning in a poster. | Meets:  
2061: 4D 6-8 #3  
NSES: B 9-12 #1  
Addresses: NSES: A 5-8 #1 |
| 5. Changing States of Matter | Matter changes state when temperature changes. | What causes matter to change its state and how is this accomplished? | Students will use an inquiry process to identify temperature as the variable that causes a substance to change from one state to another.  
They will then identify the relationship between temperature and the molecular bonds and movement in a substance.  
Students will explain the temperature conditions of a planet necessary for human life. | Meets:  
2061: 4D 6-8 #3  
NSES: B 9-12 #5  
NSES: A 5-8 #1  
Addresses: NCTM: 4, 5, 9 |
| 6. Measuring Temperature | Temperature is a measurement of the movement of atoms and molecules in a substance. Thermometers using various temperature scales measure temperature. | What does temperature actually measure and how do we measure it? | Students will identify that temperature measures the movement of atoms in a substance.  
Students will identify the thermometer as the tool and the Fahrenheit, Celsius, and Kelvin scales as the means by which we measure temperature. | Meets:  
2061: 4D 6-8 #3  
NSES: B 9-12 #5  
Addresses: NSES: A 5-8 #1  
NCTM: 4 |
## Part 3: The Planetary Temperature System

### Overview of Part 3:
Students explore the planetary temperature system. They further explore how each part influences the system and the consequences of disrupting that system.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Main Concept</th>
<th>Scientific Question</th>
<th>Objective</th>
<th>Benchmarks/Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>7. Thinking in Systems</td>
<td>Systems consist of many parts. The parts usually influence each other. A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or mismatched. Thinking about things as systems means looking for how every part relates to other parts. Any system is usually connected to other systems.</td>
<td>What are the characteristics of a system?</td>
<td>Students will explain: how a system is made up of interacting parts, that when parts of the system change it affects the system, and that systems are often related to other systems.</td>
<td>Meets: 2061: 1IA 3-5 #1 2061: 1IA 3-5 #2 2061: 1IA 6-8 #2 2061: 1IA 6-8 #3 NSES: UCP K-12 #1 Addresses: NSES: A 5-8 #1</td>
</tr>
<tr>
<td>8. The Solar System</td>
<td>The solar system is a system. One of the ways that the parts of the solar system interact with each other is through gravity.</td>
<td>How do the parts of the solar system interact with each other?</td>
<td>Students will explain the solar system as a system.</td>
<td>Meets: 2061: 1IA 3-5 #1 2061: 1IA 3-5 #2 2061: 1IA 6-8 #2 2061: 1IA 6-8 #3 2061: 4G 6-8 #2 NSES: UCP K-12 #1 NSES: D 5-8 #3 Addresses: NSES: A 5-8 #1 NCTM: 2, 5, 9 ISTE: 3, 5</td>
</tr>
<tr>
<td>9. Planetary Temperature As A System</td>
<td>The type of star and the distance of a planet from the star affect two major parts of the system that controls the surface temperature of a planet (planetary temperature system). The hotter a star is, the further the planet needs to orbit in order to maintain liquid water on its surface.</td>
<td>What are two important parts of the planetary temperature system? How do these parts work together to determine a planet's surface temperature?</td>
<td>Students will explain how the star type and the distance of a planet from its star affects the planetary temperature system.</td>
<td>Meets: 2061: 1IA 6-8 #2 NSES: UCP1 K-12 Addresses: NSES: A 5-8 #1 NCTM: 2, 5, 9</td>
</tr>
<tr>
<td>Lesson</td>
<td>Main Concept</td>
<td>Scientific Question</td>
<td>Objective</td>
<td>Benchmarks/ Standards</td>
</tr>
<tr>
<td>--------</td>
<td>--------------</td>
<td>---------------------</td>
<td>-----------</td>
<td>-----------------------</td>
</tr>
<tr>
<td>10. Atmosphere and Temperature</td>
<td>The atmosphere of a planet affects the planetary temperature system, which determines the temperature of that planet.</td>
<td>How does atmosphere affect the planetary temperature system?</td>
<td>Students will explain and illustrate that atmosphere can raise the temperature of a planet. Students put together a concept map that shows the parts of the planetary temperature system. Students will explain why atmosphere is important to habitability and how star type, distance and atmosphere all work together to determine a planet’s temperature system.</td>
<td>Meets: 2061: 11A 6-8 #2 NSES: UCP K-12 #1 NSES: A 5-8 #1 Addresses: NSES: A 5-8 #1 NCTM: 4, 5, 9</td>
</tr>
<tr>
<td>11. Atmospheric Mass</td>
<td>The amount of atmosphere on a planet depends on the planet’s gravity, which is determined by the planet’s mass.</td>
<td>What determines the amount of atmosphere on a planet?</td>
<td>Students will explain and illustrate how planetary mass affects atmosphere to effect a change in the temperature of a planet. Students will explain why a planet 1/4 to 4 times Earth’s mass is a requirement for habitability.</td>
<td>Meets: 2061: 11A 6-8 #2 NSES: UCP K-12 #1 Addresses: NSES: A 5-8 #1 NCTM: 2, 5, 9</td>
</tr>
<tr>
<td>12. Disrupting the System</td>
<td>If Jupiter were in an elliptical orbit at 1 AU, it could cause a change in Earth’s orbit, which would have consequences for the planetary temperature system.</td>
<td>What could happen if Jupiter was in an elliptical orbit at 1 AU?</td>
<td>Students explain how a planet’s orbit could be disrupted. Students explore the implications of such a disruption on the planetary temperature system and on human habitability.</td>
<td>Meets: 2061: 11A 6-8 #2 NSES: UCP K-12 #1 Addresses: NSES: A 5-8 #1 ISTE: 3, 5</td>
</tr>
</tbody>
</table>
Part 4: Unit Conclusion and Evaluation

**Overview of Part 4:** Students use an online, multimedia module to simulate the techniques that scientists might use to find a star system and planet that meet the astronomical conditions required for human habitability. Students then summarize their learning from this unit in a final project.

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Main Concept</th>
<th>Scientific Question</th>
<th>Objective</th>
<th>Benchmarks/ Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>13. Astro-Venture Mission Module Training</td>
<td>Scientists use methods such as spectroscopy, Doppler Shift, photometry and Kepler’s Third Law: to collect data from a star. They then interpret this data to determine if the star system has the astronomical conditions required for human habitability.</td>
<td>What are the chances that there is a star system other than our own that has the astronomical conditions required for human habitability? Explain.</td>
<td>Students will use the scientific inquiry process to describe the methods scientists use to find a star system that has the astronomical conditions required for human habitability.</td>
<td>Addresses: 2061: 1B 6-8, #1 NSES: A 5-8 #1 NCTM: 5, 9 ISTE: 3, 5, 6</td>
</tr>
<tr>
<td>14. Final Project</td>
<td>The astronomical requirements for habitability are not sufficient for sustaining human life on a planet. Additional requirements must be met.</td>
<td>What other requirements must a planet meet to be habitable to humans and how might a scientist determine if a planet meets these requirements?</td>
<td>Students will write a proposal to convince the &quot;World Science Foundation&quot; that the star and planet they found is worthy of further study and exploration. They will include a description of how the planet meets astronomical requirements for habitability, additional requirements that must be met, the benefits of conducting this study and the type of further study they would recommend for determining if the planet meets these additional requirements.</td>
<td>Addresses: NSES: A 5-8 #1</td>
</tr>
</tbody>
</table>
Guide to the Parts of the Lessons

Lesson Introduction and Preparation
Each lesson begins with an Overview, the Main Concept of the lesson and the Scientific Question associated with the concept. The lesson breaks down the Objectives as they are aligned with the National Education Standards and describes how these objectives will be evaluated in the Assessment. It further gives an Abstract of the lesson, breaks down the Major Concepts of the lesson and Prerequisite Concepts that students are expected to have mastered before engaging in the lesson. All of this gives the educator a good overview of what will be covered, how it will be taught and assessed.

The first part of each lesson also gives an outline of a Suggested Timeline that is based on 45-minute class periods. Time will vary depending on the educator's pacing and the student levels and dynamics of the class; however, the timeline provides some basic guidelines for the educator. Materials and Equipment and the Preparation of these materials and equipment are also described and listed so that teachers can easily see what they will need to prepare for the lesson ahead of time. Finally, a table provides suggestions on Accommodations for students that may need more support as well as Advanced Extensions for students who may need to be further challenged.

The Five “E’s”
The Astro-Venture Astronomy Lessons intend to model the scientific inquiry process by using the Five “E’s”. These stand for Engage, Explore, Explain, Extend/Apply and Evaluate. The important factor that distinguishes this lesson format from lessons of other content areas is that students are not told a concept, but are led to explore and discover the concept so that once they reach the Explain section they have an experience on which to base the concept. They are then asked to apply this new concept to other situations and are evaluated on their ability to do so.

Throughout the lessons, a Question and Answer dialogue is modeled. Of course, no class will follow this script; however, the dialogue models the kinds of discussions educators should facilitate in an effort to help guide students toward developing their own understanding of the concepts and toward drawing their own conclusions. The dialogue also models questions that stimulate higher order thinking skills rather than rote memorization of facts.

In addition, the lessons also include periodic Notes to Teacher and cues to Misconceptions. The Notes to Teacher provide additional background information or suggestions that may be helpful to the educator. The educator may determine that some of the information is appropriate to share with their students, while other information is not. It is hoped that by alerting the educator to Misconceptions that educators will try to bring out these misconceptions with their students and help their students to address the misconceptions. Misconceptions are one of the most challenging areas for science educators, because research shows that we must disprove our own misconceptions before we can accept new concepts. We cannot be told these concepts, but must discover them ourselves.

Engage
The Engage section of each lesson provides guidelines for drawing on students' prior knowledge, building on previous lesson concepts, introducing the purpose of the lesson and the Scientific Question that will be explored.

Explore
In the Explore section, students make Predictions or Hypotheses in response to the Scientific Question and are given an activity that will help them to collect data and evidence to answer the Scientific Question.

Explain
In the Explain section, students reflect on the explore activity by recording their Results and Conclusions. They discuss these as a class or in small groups and receive feedback on their ideas. They may also engage in readings or additional demonstrations that provide further explanation of the concepts they have explored.
Extend/Apply
In the Extend/Apply section, students are given an activity or assignment in which they demonstrate their understanding of the concept and/or apply it to another situation. Again they receive feedback on their learning.

Evaluate
In the Evaluate section, students are evaluated on their understanding of the concept. Often rubrics are provided for evaluation of this learning. In addition, students discuss and summarize the main concepts of the lesson, which is posted on the wall so students can see how the concepts build on each other.

Lesson Blacklines
The end of each lesson includes the blacklines needed for class set duplication or for creating transparencies for that particular lesson. These can be printed out and duplicated, as needed. Astro Journals are included for most lessons and model the scientific inquiry process used throughout each lesson.

Rubrics
Almost all of the assignments in Astro-Venture have a rubric for evaluation. Generally, these rubrics are included directly on the assignment sheets so that students know what they are expected to do. Before the students begin the assignment, the teacher should go over the rubric so that everyone understands the expectations.

When using the rubrics to evaluate student work, there are a few things to keep in mind that will make the process easier and more effective.

1. The teacher should spend some time thinking about the assignment and the rubric before reviewing it with the students. The teacher's thoughts may change after discussing it with the students, but everyone will benefit from the teacher knowing what she is expecting.

2. The four levels of the rubric describe general levels of proficiency. Few assignments will ever be exactly a '3' or exactly a '2'. Certain expectations will be met more proficiently than others. To assign a score, the teacher should identify the score that "best fits" the work. If there is a great discrepancy, then the teacher can consider multiple scores although this will create more work and difficulties in reporting.

3. Written assignments such as essays focus on content and reasoning. The teacher may also use district standards for evaluating the writing process.

4. Visual assignments such as illustrations do include expectations for the appearance of the illustration. The focus of these expectations is the clarity of the information being presented in the illustration. Despite the great advancements in digital imaging technology, botanists, entomologists, and archeologists (among others) still rely on specially trained artists to record new findings. The ability to express visual information clearly and accurately is a skill worth developing. Appearance cannot substitute for the accuracy of the information, but it can enhance the expression of this information. That enhancement is worth acknowledging.

Scientific Inquiry Evaluation Rubric For Evaluating Astro Journal Entries
There are many ways of approaching rubrics for assessment, each with its own strengths and weaknesses. Whatever the approach the goal is the same, providing feedback for students so that they can meet or exceed the standards or other expectations upon which they are focusing.
With this goal in mind, it is essential that students have many opportunities to work with the rubric: clarifying and analyzing the expectations, going over assessed work to understand the scores, evaluating their own work and their peers’ work, and coming up with evidence to explain and justify those scores. Rubrics are only useful as long as they help students to understand how to improve their work and aid in their learning process.

The following rubric for inquiry in the Astro Journal divides the Astro Journal steps into four components and states expectations for each of those components. Scoring is done for each component in reference to the degree to which the expectations are met.

<table>
<thead>
<tr>
<th>Component</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis/Prediction</td>
<td>• Clearly stated&lt;br&gt;• Specific enough to be testable/observable and give a meaningful result&lt;br&gt;• Has basis in solid information or observations and a logical reasoning process</td>
</tr>
<tr>
<td>Materials, Procedures, and Data</td>
<td>• Clearly stated&lt;br&gt;• Complete&lt;br&gt;• Accurate and tied directly to hypothesis and scientific question</td>
</tr>
<tr>
<td>Results</td>
<td>• Clearly stated&lt;br&gt;• Refers directly to Scientific Question and data&lt;br&gt;• Draws a reasonable conclusion from that data</td>
</tr>
<tr>
<td>Conclusions</td>
<td>• Clearly stated&lt;br&gt;• States how hypothesis/prediction was confirmed and/or altered&lt;br&gt;• Refers directly to findings, observations, and/or data to explain why thoughts were changed.</td>
</tr>
</tbody>
</table>

Scores:
4: Expectations Exceeded
3: Expectations Met
2: Expectations Not Quite Met
1: Expectations Not Met

The score of ‘3’ indicates that the expectations were met. The score of ‘4’ indicates that the expectations were exceeded. The difference between those two scores is somewhat subjective and should be worked on by each teacher (or group of teachers trying to use the rubric in a standard fashion). The score of ‘2’ indicates that expectations were not quite met while the score of ‘1’ indicates that the expectations were not met. The difference between those two scores is again somewhat subjective, but some thought into the implications of these scores might be helpful in distinguishing between the two. A ‘2’ indicates that the student needs some assistance and work in meeting the expectations. A ‘1’ indicates the student needs much assistance and work in meeting the expectations.

For this reason, just providing the students with a score, especially students with scores of ‘2’ or ‘1’ is not enough feedback. The student needs to know the reasons why a particular score was given. (Note: even students with scores of ‘3’ and ‘4’ benefit from learning why their work received the scores that it did. Many of these students are not conscious of what they did to receive those scores and might not repeat what they did, if it is not made explicit to them.)
Consider the following example. In Lesson 5: Properties of Matter, the students have to develop a hypothesis about what causes matter to change state. Here are three sample (fictional) responses.

(A) Heat causes matter to change its state. I’ve watched ice cubes melt outside of the freezer and I’ve watched water turn to steam when you heat it up.

(B) Temperature causes matter to change its state.

(C) Particles go into stuff and energize it because matter is just energy.

Response 'A' is clearly stated and specific enough to be tested leading to a meaningful result. It also has an explanation that is based on solid observation and reasoning. The fictional student is saying that she has made two observations that show a consistent pattern that explains the phenomena - a logical reasoning process. Notice that the hypothesis is not quite correct. Regardless of that fact, the hypothesis should score at least a '3' and possibly a '4' depending on how the teacher and students understand the rubric.

Response 'B' is not grounded in any information or observations and shows no evidence of a reasoning process. In certain ways, it is not even clear. In short, this hypothesis should score only a '2,' and the student should be told to base his hypothesis in more solid information or observations and to indicate how the hypothesis was reasoned from those sources.

Response 'C' is not very clear. The student may or may not have based this hypothesis on solid information, observations, and reasoning. You, as the teacher, just do not know. The hypothesis should score only a '2' or possibly even a '1'. In the long run, the actual score of the hypothesis is less important than the student learning what is needed in order to meet the expectations and put together a good hypothesis.

In conclusion, using this rubric will require an investment of time and energy by teacher and students in creating an understanding of what these expectations mean and how they will be demonstrated in student work. If that process leads to changes in the rubric, so much the better. All the participants in that process will have a richer understanding of the process and will be better poised to engage in authentic inquiry experiences.
Educational Standards List

Benchmarks for Science Literacy (2061)

1 The Nature of Science
   A. The Scientific World View
   B. Scientific Inquiry
   C. Scientific Enterprise

2 The Nature of Mathematics
   A. Patterns and Relationships
   B. Mathematics, Science and Technology
   C. Mathematical Inquiry

3 The Nature of Technology
   A. Technology and Science
   B. Design and Systems
   C. Issues in Technology

4 The Physical Setting
   A. The Universe
   B. The Earth
   C. Processes That Shape the Earth
   D. Structure of Matter
   E. Energy Transformations
   F. Motion
   G. Forces of Nature

5 The Living Environment
   A. Diversity of Life
   B. Heredity
   C. Cells
   D. Interdependence of Life
   E. Flow of Matter and Energy
   F. Evolution of Life

6 The Human Organism
   A. Human Identity
   B. Human Development
   C. Basic Functions
   D. Learning
   E. Physical Health
   F. Mental Health

7 Human Society
   A. Cultural Effects on Behavior
   B. Group Behavior
   C. Social Change
   D. Social Trade-Offs
   E. Political and Economic Systems
   F. Social Conflict
   G. Global Interdependence

8 The Designed World
   A. Agriculture
   B. Materials and Manufacturing
   C. Energy Sources and Use
   D. Communication
   E. Information Processing
   F. Health Technology

9 The Mathematical World
   A. Numbers
   B. Symbolic Relationships
   C. Shapes
   D. Uncertainty
   E. Reasoning

10 Historical Perspectives
   A. Displacing the Earth from the Center of the Universe
   B. Uniting the Heavens and Earth
   C. Relating Matter and Energy and Time and Space
   D. Extending Time
   E. Moving the Continents
   F. Understanding Fire
   G. Splitting the Atom
   H. Explaining the Diversity of Life
   I. Discovering Germs
   J. Harnessing Power

11 Common Themes
   A. Systems
   B. Models
   C. Constancy and Change
   D. Scale

12 Habits of the Mind
   A. Values and Attitudes
   B. Computation and Estimation
   C. Manipulation and Observation
   D. Communication Skills
   E. Critical-Response Skills
National Science and Education Standards (NSES)

Unifying Concepts and Processes (UCP)

K-12
1. Systems, order and organization
2. Evidence, models and explanation
3. Change, constancy, and measurement
4. Evolution and equilibrium
5. Form and function

Content Standard A: Science as Inquiry

K-12
1. Abilities necessary to do scientific inquiry
2. Understanding about scientific inquiry

Content Standard B: Physical Science

K-4
1. Properties of objects and materials
2. Position and motion of objects
3. Light, heat, electricity and magnetism

5-8
1. Properties and changes of properties in matter
2. Motions and forces
3. Transfer of energy

9-12
1. Structure of atoms
2. Structure and properties of matter
3. Chemical reactions
4. Motions and forces
5. Conservation of energy and increase in disorder
6. Interactions of energy and matter

Content Standard C: Life Science

K-4
1. Characteristics of organisms
2. Life cycle of organisms
3. Organisms and environments

5-8
1. Structure and function in living systems
2. Reproduction and heredity
3. Regulation and behavior
4. Populations and ecosystems
5. Diversity and adaptations of organisms

9-12
1. The cell
2. Molecular basis of heredity
3. Biological evolution
4. Interdependence of organisms
5. Matter, energy and organization in living systems
6. Behavior of organisms

Content Standard D: Earth and Space Science

K-4
1. Properties of earth materials
2. Objects in the sky
3. Changes in earth and sky

5-8
1. Structure of the earth system
2. Earth's history
3. Earth in the Solar System

9-12
1. Energy in the earth systems
2. Geochemical cycles
3. Origin and evolution of the earth system
4. Origin and evolution of the universe

Content Standard E: Science and Technology

K-4
1. Abilities to distinguish between natural objects and objects made by humans
2. Abilities of technological design
3. Understanding about science and technology

5-12
1. Abilities of technological design
2. Understandings about science and technology

Content Standard F: Science in Personal and Social Perspectives

K-4
1. Personal Health
2. Characteristics and changes in population
3. Types of resources
4. Changes in environments
5. Science and technology in local challenges

5-8
1. Personal Health
2. Populations, resources and environments
3. Natural hazards
4. Risks and benefits
5. Science and technology in society

9-12
1. Personal and community health
2. Population growth
3. Natural resources
4. Environmental quality
5. Natural and human-induced hazards
6. Science and technology in local, national and global challenges
Content Standard G: History and Nature of Science

K-4
5. Science as a human endeavor

5-8
1. Science as a human endeavor
2. Nature of science
3. History of science

9-12
1. Science as a human endeavor
2. Nature of scientific knowledge
3. Historical perspectives

National Council of Teachers of Mathematics (NCTM) Standards

STANDARD 1: NUMBER AND OPERATION
Mathematics instructional programs should foster the development of number and operation sense so that all students—
• understand numbers, ways of representing numbers, relationships among numbers, and number systems;
• understand the meaning of operations and how they relate to each other;
• use computational tools and strategies fluently and estimate appropriately.

STANDARD 2: PATTERNS, FUNCTIONS, AND ALGEBRA
Mathematics instructional programs should include attention to patterns, functions, symbols, and models so that all students—
• understand various types of patterns and functional relationships;
• use symbolic forms to represent and analyze mathematical situations and structures;
• use mathematical models and analyze change in both real and abstract contexts.

STANDARD 3: GEOMETRY AND SPATIAL SENSE
Mathematics instructional programs should include attention to geometry and spatial sense so that all students—
• analyze characteristics and properties of two- and three-dimensional geometric objects;
• select and use different representational systems, including coordinate geometry and graph theory;
• recognize the usefulness of transformations and symmetry in analyzing mathematical situations;
• use visualization and spatial reasoning to solve problems both within and outside of mathematics.

STANDARD 4: MEASUREMENT
Mathematics instructional programs should include attention to measurement so that all students—
• understand attributes, units, and systems of measurement;
• apply a variety of techniques, tools, and formulas for determining measurements.

STANDARD 5: DATA ANALYSIS, STATISTICS, AND PROBABILITY
Mathematics instructional programs should include attention to data analysis, statistics, and probability so that all students—
• pose questions and collect, organize, and represent data to answer those questions;
• interpret data using methods of exploratory data analysis;
• develop and evaluate inferences, predictions, and arguments that are based on data;
• understand and apply basic notions of chance and probability.
STANDARD 6: PROBLEM SOLVING
Mathematics instructional programs should focus on solving problems as part of understanding mathematics so that all students—
• build new mathematical knowledge through their work with problems;
• develop a disposition to formulate, represent, abstract, and generalize in situations within and outside mathematics;
• apply a wide variety of strategies to solve problems and adapt the strategies to new situations;
• monitor and reflect on their mathematical thinking in solving problems.

STANDARD 7: REASONING AND PROOF
Mathematics instructional programs should focus on learning to reason and construct proofs as part of understanding mathematics so that all students—
• recognize reasoning and proof as essential and powerful parts of mathematics;
• make and investigate mathematical conjectures;
• develop and evaluate mathematical arguments and proofs;
• select and use various types of reasoning and methods of proof as appropriate.

STANDARD 8: COMMUNICATION
Mathematics instructional programs should use communication to foster understanding of mathematics so that all students—
• organize and consolidate their mathematical thinking to communicate with others;
• express mathematical ideas coherently and clearly to peers, teachers, and others;
• extend their mathematical knowledge by considering the thinking and strategies of others;
• use the language of mathematics as a precise means of mathematical expression.

STANDARD 9: CONNECTIONS
Mathematics instructional programs should emphasize connections to foster understanding of mathematics so that all students—
• recognize and use connections among different mathematical ideas;
• understand how mathematical ideas build on one another to produce a coherent whole;
• recognize, use, and learn about mathematics in contexts outside of mathematics.

STANDARD 10: REPRESENTATION
Mathematics instructional programs should emphasize mathematical representations to foster understanding of mathematics so that all students—
• create and use representations to organize, record, and communicate mathematical ideas;
• develop a repertoire of mathematical representations that can be used purposefully, flexibly, and appropriately;
• use representations to model and interpret physical, social, and mathematical phenomena.
International Society for Technology in Education (ISTE) Standards

TECHNOLOGY FOUNDATION STANDARDS FOR STUDENTS

1. Basic operations and concepts
   • Students demonstrate a sound understanding of the nature and operation of technology systems.
   • Students are proficient in the use of technology.

2. Social, ethical, and human issues
   • Students understand the ethical, cultural and societal issues related to technology.
   • Students practice responsible use of technology systems, information and software.
   • Students develop positive attitudes toward technology uses that support lifelong learning, collaboration, personal pursuits and productivity.

3. Technology productivity tools
   • Students use technology tools to enhance learning, increase productivity and promote creativity.
   • Students use productivity tools to collaborate in constructing technology-enhanced models, prepare publications and produce other creative works.

4. Technology communications tools
   • Students use telecommunications to collaborate, publish and interact with peers, experts and other audiences.
   • Students use a variety of media and formats to communicate information and ideas effectively to multiple audiences.

5. Technology research tools
   • Students use technology to locate, evaluate and collect information from a variety of sources.
   • Students use technology tools to process data and report results.
   • Students evaluate and select new information resources and technological innovations based on the appropriateness for specific tasks.

6. Technology problem-solving and decision making tools
   • Students use technology resources for solving problems and making informed decisions.
   • Students employ technology in the development of strategies for solving problems in the real world.
Part 1: Unit Introduction Lessons
Students are introduced to the basic requirements for human survival. Using an online, multimedia module, they change factors of our Solar System and draw conclusions about which factors are necessary for human survival.

**Main Lesson Concept:** Humans need water, oxygen, food, gravity, a moderate temperature and protection from poisonous gases and high levels of radiation to survive.

**Scientific Question:** What basic requirements do humans need to survive? Why?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will research and list the basic requirements for human survival in their Astro Journals.</td>
<td>Meets: 2061: 6C 3-5 #1, 2</td>
</tr>
<tr>
<td>They will write a survival story identifying these basic requirements, the consequences of not meeting them and how they are met.</td>
<td>NSES: F 5-8, #1</td>
</tr>
<tr>
<td>After comparing characteristics of the Earth with other planets and moons, students will predict which features of the Earth they believe are crucial to human survival.</td>
<td>Addresses: 2061 4B 6-8 #2</td>
</tr>
<tr>
<td></td>
<td>NSES: A 5-8 #1</td>
</tr>
<tr>
<td></td>
<td>ISTE: 3, 5</td>
</tr>
</tbody>
</table>

**Assessment**

Write-up in Astro Journal.

**Abstract of Lesson**

Students are introduced to the overall goals and concepts of Astro-Venture and are given the background information for the Astronomy unit and final project. Students research the requirements for human survival and analyze the planets and moons in our solar system to assess the ability of each to support human survival.

**Prerequisite Concepts**

- Energy is the capacity to do work (make an object move).
- Information taken from a book, Web site or other resource is not always accurate. It is important to check the reputation of the source and to find several sources that agree.

**Major Concepts**

- Humans need food, because it gives us energy so that we can move, grow and function. It also gives us nutrients to build and repair bones, teeth, nails, skin, hair, flesh and organs.
- Humans need oxygen, because it helps us to obtain energy from sugars.
- Humans need water, because it allows nutrients to circulate through the body. It also allows the body to filter out waste and poisons and helps to regulate our body temperature.
- Humans need a moderate temperature to prevent the body temperature from going above or below 98.6° F/37°C.
- Humans need protection from high levels of radiation and poisonous gases to prevent cancer, disease and damage to the body.
- Humans need gravity for normal development and function of our bodies.
- Earth is the only planet that we know of that can meet our requirements for human survival.
Part 1  Unit Introduction  Astronomy Training Module

Suggested Timeline (45-minute periods):
Day 1: Engage and Explore Part 1 Sections
Day 2: Explore Part 2 Section
Day 3: Explain Section
Day 4: Extend/Apply and Evaluate Sections

Materials and Equipment:
- An overhead transparency of the Astro-Venture Academy Letter of Acceptance
- A class set of the Astro-Venture Materials Packets
- A class set of Astro Journal Lesson 1: Unit Introduction *
- A class set of Survival Story
- 1 Planetary Comparison Chart for each group
- A class set of Human Requirements Reading
- Books, CD-ROMs or other resources on human survival needs, human health, biology or astrobiology.
- Chart Paper
- Overhead projector

Preparation:
- Gather resources (i.e., books, CD-ROMS etc.)
- Make overhead transparency of Astro-Venture Academy Letter of Acceptance.
- Duplicate a class sets of Astro-Venture Materials Packets, Astro Journals, Survival Story and Human Requirements Reading.
- Prepare copies of Planetary Comparison Charts for each group.
- Prepare chart paper with major concept of the lesson and human survival needs to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal is included with the Instructional Materials. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations
For students who may have special needs, provide extra support for reading assignment (e.g. partner, read aloud, etc.).

Advanced Extensions
- Research what a chosen microbe* needs to survive.
- Create a Venn Diagram comparing and contrasting microbes’ needs with human needs.

*Suggested microbes: bacillus anthracis (anthrax) thermus aquaticus or pyrococcus furiosus.
1. **Introduce Astro-Venture.**
   - Project the overhead transparency of the Astro-Venture Academy Acceptance Letter.
   - Read over the letter with students. Emphasize the overall concept, goal and purpose of Astro-Venture:
     - **Question:** Why would we be interested in the study of life in the universe?
       - **Answers may include:** We are interested in the study of life in the universe in order to better understand life on Earth; to find out if life on Earth is unique; to better understand how life began and evolved; or to improve human ability to survive on other planets.
     - **Question:** Why would we want to study our own planet and star system’s ability to support human life?
       - **Answer:** This will help us understand what kinds of places to look for in the universe that could also support human life.
     - **Question:** Why might we want to find other planets like Earth?
       - **Answers may include:** We may want to find other planets like Earth in order to find other forms of life and discover how this life might compare to life on Earth; to find out if we are alone in the universe; or to better understand how our planet, Solar System and life formed and evolved.
     - Say: Your goal as Astro-Venture scientists will be to determine what characteristics of Earth and our Solar System allow humans to survive and to find and design a planet and star system that meet these requirements.

2. **Hand out the of Astro-Venture Materials Packets.**
   Have students read through the materials individually or as a class. Go over the major goals and activities with students.
   - **Question:** What is the major goal of the Astro-Venture Academy?
     - **Answer:** The major goal of the Astro-Venture Academy is to find, study, and design planets that would be habitable to humans.
   - **Question:** What kinds of activities will we participate in to achieve this goal?
     - **Answer:** We will participate in online training modules, off-line investigations, online mission modules, and Design a Planet module to help with this goal.
   - **Question:** In this unit, we will focus on Astronomy. What are the goals of the Astronomy section of Astro-Venture?
     - **Answer:** The goals of the Astronomy section are to identify the astronomical features of our star system and planet that support human habitation, why we need these features and how we might go about finding a star system and planet like this.
3. **Introduce the Scientific Question of the lesson.**
   - **Scientific Question:** What do humans need to survive? Why?
   - Tell students that they will be conducting research to help answer this question.

**Explore  Part 1 - (approximately 25 minutes)**

1. **Ask students what they think are basic requirements for human survival.**
   - Record answers on the board or chart paper. Accept all answers.
   - **Answers may include:** Humans need food, water, shelter from cold or heat, air or oxygen, love to survive.
   - **Question:** Looking at this list, is there anything that we could live without?
   - **Answers may vary.**
     Note to Teacher: Students may have included things like cookies, TV, house, furniture, car or other luxuries that are nice but not necessary for survival. Allow them to decide which items they agree are really essential for survival. If students listed love or companionship, encourage a debate about whether we could survive without these things. Psychological needs are not a main focus of Astro-Venture; however, they are important to acknowledge.

2. **Introduce students to their research assignment.**
   - Refer to the list of human needs the class has composed.
   - **Question:** Why do we need food? What would happen to us, if we didn't have food?
     - **Answers may vary and should be accepted without feedback on whether they are correct or incorrect.**
   - Repeat this question for the other elements on the list, and accept all answers without feedback. At this point students are not expected to know why each element is needed.
   - Tell students that they will be doing some research of health, biology, survival and astrobiology resources to see if there are any needs they left off their list and to see why we need each element.

3. **Have students complete the Prediction section of their Astro Journal.**
Astro-Venture: Astronomy Educator Guide EG-2002-10-001-ARC

Part 1 - Unit Introduction

Astronomy Training Module

Explore  Part 2 - (approximately 45 minutes)

1. Have students conduct research on the Internet, CD-ROMs and in books that have topics on health, survival and biology.
   They should research human survival needs and the effects on the human body when these needs are not met, to see if their predictions were accurate. They should record their findings in the Data section of their Astro Journal and bibliographic information of the resources they used in the Materials section of their Astro Journal.

[Web sites] Have students try key words such as anatomy, physiology, health, biology, human body and nutrition at the following search engines and directories for kids:
- Yahooligans!  http://www.yahooligans.com
- Ask Jeeves for Kids  http://www.ajkids.com
- Ithaki for Kids  http://www.ithaki.net/kids
- Cyber Sleuth Kids  http://cybersleuth-kids.com
- Kids Click  http://sunsite.berkeley.edu/kidsclick

The following encyclopedia Web sites can also be useful:
- Columbia Encyclopedia  http://www.encyclopedia.com
- Microsoft Encarta  http://encarta.msn.com

Explain  (approximately 45 minutes)

1. Students share and compare their results with a partner or small group.
   They identify which elements and reasons they have in common and share these with the whole class.

2. List any new elements on the class list that the class agrees is supported by evidence.
   Have students share the reasons each element is needed.

3. Read with students the Human Requirements Reading.
   Have students answer the reading comprehension questions.
4. Go over the human requirements described in the reading and compare them with the requirements the class listed. Create a final chart like the one below and post this in the classroom for the duration of the unit.

- Question: What do humans need to survive and why?
- Answer: Humans need food, water, oxygen, moderate temperature and protection from poisonous gases and high levels of radiation.

<table>
<thead>
<tr>
<th>Humans need:</th>
<th>Reason:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Food</td>
<td>Gives us energy so that we can move, grow and function. It also gives us nutrients to build and mend bones, teeth, nails, skin, hair, flesh and organs.</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Helps us to obtain energy from sugars.</td>
</tr>
<tr>
<td>Water</td>
<td>Allows nutrients to circulate through the body, allows the body to filter out waste and poisons and helps to regulate body temperature.</td>
</tr>
<tr>
<td>Moderate temperature</td>
<td>Allows us to maintain an average body temperature of 98.6º F/37ºC and to maintain water in a liquid state at all times.</td>
</tr>
<tr>
<td>(Average global temperature below 50º C)</td>
<td></td>
</tr>
<tr>
<td>Protection from poisonous gases and high levels of radiation</td>
<td>To prevent cancer, disease and damage to the body.</td>
</tr>
<tr>
<td>Gravity</td>
<td>Allows our biological systems to develop and function normally.</td>
</tr>
</tbody>
</table>

5. Students record results and conclusions in the Results and Conclusion sections of their Astro Journal.

**Extend/Apply** (approximately 20 minutes)

1. Discuss how human survival needs listed on the chart are met on Earth.
   - Question: How is our requirement for food met on Earth?
   - Answer: (Accept all answers without feedback whether they are correct or incorrect.) We gain energy and nutrients from plants and animals that we eat. This energy first comes from the Sun.

   - Repeat this discussion for each of the elements on this list. At this point, students may not know all of the answers. They may not know how a moderate temperature is maintained or how we are protected from poisonous gases and radiation. These answers will be discussed throughout Astro-Venture.

2. Introduce the planet comparison activity.
   - Divide students into groups. Assign each group a different planet to compare with Earth.
• Have students look at the Planet Comparison Chart and determine whether the planet would be habitable or not. If they determine that the planet would not be habitable, have them explain which factors on the human requirements charts will not be met and why.

3. **Students share their assessments as a class.**
   Based on what students know so far, their assessments should include observations that these planets do not have oxygen, and most have no liquid water and have temperatures that are far too extreme for humans.

---

**Evaluate** (approximately 25 minutes)

1. **Have students write a story using the Survival Story guidelines and Rubric.**
   In this story, students should describe a situation in which someone’s survival is endangered and why their survival is endangered.
   
   • Go over rubric for story.

2. **Students share stories with the class and provide feedback on the accuracy of the survival elements included.**

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding. For this lesson, the chart of what is needed and why should also be posted.
Dear applicant,

After extensive review of your application, the admissions committee is pleased to accept you to the Astro-Venture Academy. At this prestigious academy, you will have the opportunity to train and work with NASA scientists, as you explore the fascinating field of astrobiology: the study of life in the universe. Your research will focus on the search for and design of a planet that will support human habitation.

In preparation for your entrance to the academy, please review the enclosed materials.

Sincerely Yours,

Dr. Wentz

Dr. Wentz
Director of Admissions
Astro-Venture Academy
Astro-Venture Academy Materials Packet

The Astro-Venture Academy

The Astro-Venture Academy is a virtual academy that you can attend using the Internet. Your school is one of a select group of schools and universities all over the world who are working together to study, find and design habitable planets. As a member school, you will be expected to complete the online training and mission modules as well as the off-line classroom explorations. This will be challenging, but the rewards will be great if you succeed in finding and designing a planet that can support human life! Good luck!

Academy Resources

During your studies and research, you will be able to use the academy’s many instruments. These include:

- Telescopes that are orbiting the Earth above the atmosphere, where more information can be collected.
- Probes that can be sent out to other star systems and planets.

You will also have the opportunity to interact with many NASA scientists and specialists who will assist you along the way. You will be able to learn about many different jobs in astrobiology by reading these specialists’ career facts sheets, collecting their trading cards and interacting with them in live webcasts and chats.

What is Astrobiology?

- How did life begin?
- Are we alone in the universe?
- What is the future of life?

These are the questions that astrobiologists are working to answer. Astrobiology is the study of life on Earth and in the universe. Astrobiologists want to have a better understanding of life on Earth and to find out if life on Earth is unique. They study all life forms on Earth. They are especially interested in microbial life, which can only be seen with a microscope. They are interested in studying microbes because they were the first life forms on Earth. Also, many microbes have the ability to live in extreme environments that are too hot or too cold for human survival or the environments have no oxygen. At the Astro-Venture Academy, we focus on human life, so that we can have a better understanding of ourselves and our own survival requirements.

Research Areas

At the Academy, you will explore four research areas:

1. Astronomy
2. Geology
3. Atmospheric sciences
4. Biology

Training

In each of these online modules, you will be trained on the requirements for human habitation that relate to that area of science. In these modules, you learn what humans need in a planet and star system to survive.
Investigations
Off-line, you will engage in many classroom investigations in which you will learn why humans need the requirements identified in the Training modules.

Missions
After your training, you will engage in online missions to search for a star system and planet that meet these qualifications. In these modules, you learn how to go about finding a planet that would support human survival.

Design a Planet
Once you’ve completed all four sections, you will engage in the online Design a Planet Module in which you will design a simulated star system and planet that meets all human survival requirements in all four areas: astronomy, geology, atmospheric sciences and biology.

Astronomy
As a Junior Astronomer, you will complete the online Astronomy Training module to discover the astronomical features of our Solar System that make Earth habitable for humans. When you have successfully completed your training, you will earn your badge and be promoted to Senior Astronomer. You will then engage in off-line Astronomy investigations, and you will discover why we need the features identified in Astronomy Training. Finally, you will proceed to your online Astronomy Mission where you will work with NASA scientists to find a star system and planet with the astronomy features that will support human life.

Final Astronomy Project
If you are successful in finding a planet and star system that meets the astronomical requirements for human life, write a proposal to the World Science Foundation to convince them that the star and planet you find is worthy of further study and exploration. Include evidence of why the star and planet needs further study, what we could learn from this study and what type of further exploration you would recommend.

Featured Astronomy Careers
The careers featured in this unit are astrophysicists and astrobiologists. You will learn about the following areas of specialty in astrophysics:
- Spectroscopy
- Doppler Shift
- Photometry
- Habitable Zone
The following career fact sheets give more detail about these careers and people in these careers.
Astrobiologist

**Related Job Titles:**
Exobiologist, life scientist, space scientist

**Job Description:**
Astrobiologists study life in the universe: how it began, where it's located and how it has evolved or changed over time. Three main questions drive their research: How did life begin and evolve? Is there life elsewhere in the universe? What is the future for life on Earth and beyond? Astrobiologists need to understand how many different kinds of science work together. These kinds of science may include biology (microbiology, botany, physiology, zoology), chemistry, physics, geology, paleontology and astronomy. Some astrobiologists spend time writing proposals to ask for funding for their research. They usually work regular hours in laboratories and use microscopes, computers and other equipment. Some use plants and animals for experiments. Many do research outside, and many work with a team.

**Interests / Abilities:**
- Do you enjoy doing experiments?
- Are you interested in how animals and plants function?
- Are you curious about whether there is other life in the universe?
- Do you work well on your own?
- Do you work well with a team?
- Do you enjoy investigating mysteries or problems?

**Suggested School Subjects / Courses:**
- Science (biology, chemistry, physics, astronomy, planetary science with laboratory research and fieldwork)
- Math

**Areas of expertise:**
- **Chemical and biological evolution:** study what life is, where it's located, how it began and changed over time
- **Biogeochemistry:** study rocks for evidence of life
- **Microbiology:** study microscopic organisms and the conditions of the environments where they can survive (especially very hot/cold environments)
- **Solar system analysis:** research and design new experiments and instruments to explore the Solar System

**Education / Training Needed:**
The minimum education required for this position is a bachelor's degree in biology, astronomy, space science, chemistry or another appropriate subject from an accredited college or university. This course of study must include at least 20 semester hours of physical science or engineering or experience that leads to the understanding of the equipment used for manned aerospace flights. To do research, a Ph.D. is highly desired for this position.

**Additional Resources:**
- NASA Office of Space Science
  [http://www.hq.nasa.gov/office/oss](http://www.hq.nasa.gov/office/oss)
- NASA Office of Life and Microgravity Sciences and Applications
  [http://www.hq.nasa.gov/office/oumsa](http://www.hq.nasa.gov/office/oumsa)
- Astrobiology at NASA
  [http://astrobiology.arc.nasa.gov](http://astrobiology.arc.nasa.gov)
- The Astrobiology Web
  [http://www.astrobiology.com](http://www.astrobiology.com)
- NASA Specialized Center of Research and Training (NSCORT)/Exobiology
  [http://exobi.ucsd.edu](http://exobi.ucsd.edu)
- American Institute of Biological Sciences
  [http://www.aibs.org](http://www.aibs.org)
- American Physiological Society
  [http://www.faseb.org/aps](http://www.faseb.org/aps)
- Biotechnology Industry Organization
- Biophysical Society
  [http://www.biophysics.org/biophys/society/biohome.htm](http://www.biophysics.org/biophys/society/biohome.htm)

**What can I do right now?**
- Join a local environmental club or organization.
- Participate in Earth Day activities.
- Take summer jobs or internships at parks, farms, plant nurseries, laboratories, museums or camps.
- Visit Astro-Venture regularly to participate in chats and activities.
- Call the American Association of Science and Technology Centers for Information on science museums in your area that you might visit.
(202) 783-7200
- Participate in science fair projects.
Astrophysicist

Related Job Titles:
Space scientist, astronomer, research scientist, physicist, planetary scientist, space physicist, dynamicist, planetary spectroscopist, galactic astronomer, stellar spectroscopist

Job Description:
Astrophysicists study objects in the universe including galaxies and stars to understand what they are made of, their surface features, their histories and how they were formed. To study these bodies, astrophysicists often come up with new tools and ways to investigate them. Astrophysicists spend most of their time in laboratories and offices looking at a lot of information gathered by instruments such as telescopes, sensors and probes, deciding what the information means and writing papers and reports about what they find. Some also spend time discovering rules about how objects in space are formed or structured. A small portion of an astrophysicist's time is spent actually making observations with instruments. This may require travel to faraway locations and is done at night.

Interests / Abilities:
- Do you enjoy math and science?
- Do you have a good imagination?
- Do you work well on your own?
- Do you enjoy working with computers?
- Do you enjoy solving mysteries or problems?
- Do you enjoy learning about new things?
- Do you do well in math and science?

Suggested School Subjects / Courses:
- physics
- chemistry
- astronomy
- electronics
- mathematics

Education / Training Needed:
The minimum education required for this position is a bachelor's degree in physics, mathematics, astrophysics, astronomy or a related subject from an accredited college or university. This study must include one physics, or engineering lab in aerospace instrumentation. To do research, a Ph.D. is highly desired for this position.

Areas of expertise:
- Solar studies: study the Sun
- Stellar studies: study the Sun and other stars
- Planetary studies: study planets, moons, asteroids, meteoroids and comets
- Optical physics: design and develop instruments that measure radiation
- Atmospheres and ionospheres: study atmospheres on Earth, other planets and moons
- Fields and particles: study magnetic, gravitational and electric fields in space

Additional Resources:
- SETI Institute Online (Search for Extraterrestrial Intelligence) http://www.seti.org
- American Institute of Physics http://www.aip.org
- The American Physical Society http://www.aps.org
- American Astronomical Society (request a pamphlet with information on careers in astronomy) http://www.aas.org
- Yvonne Pendleton's Astronomy Web site for students (Yvonne is a NASA astrophysicist) http://web99.arc.nasa.gov/~yvonne
- The Planetary Society http://www.planetary.org

What can I do right now?
- Visit Astro-Venture regularly to participate in chats and activities.
- Visit a planetarium or observatory near you.
- Call the American Association of Science and Technology Centers for information on science museums in your area that you might visit (202) 783-7200.
- Join an astronomy club.
- Buy an inexpensive telescope and study the stars from home.
- Read Astronomy and Sky and Telescope magazines.
- Ask your teacher to sign up for Astro, a program where astronomers visit your classroom.
- Attend U.S. Space Camp for a week-long program on astronomy and space sciences.
**How I first became interested in this profession:**

I was inspired by the Apollo Program. I lived in Key West, Florida until I was thirteen, and I remember watching the Apollo rockets on clear days, as they arched overhead from their Cape Kennedy lift-off. I would stand there looking upward, promising myself that someday I would be a part of NASA, the great agency that could take us into space.

**What helped prepare me for this job:**

As a teenager, I spent every spare minute at the Fernbank Science Center in Atlanta, Georgia, where I was surrounded by scientists. In college, I was often the only woman in my aerospace engineering classes. I found out I was a very determined person, and that helped me overcome obstacles that being in a male-dominated environment presented. College life was demanding and there was little time off. I wish I would have known then what I know now -- that the long hours and hard work were well worth it.

**My role models or inspirations:**

My sister has always been a role model, because she got her Ph.D. in statistics and inspired me to stay in school. The scientists at the Fernbank Science Center were also a great source of inspiration to me.

**My education and training:**

- Ph.D. in Astrophysics
- M.S. in Aeronautics and Astronautics
- B.S. in Aerospace Engineering

**My career path:**

- Twenty years as an astrophysicist at NASA

**What I like about my job:**

I get the freedom to be as creative as I can be, scientifically. I get to choose the projects I want to investigate. The universe is a puzzle and I get to find some of the pieces.

**What I don’t like about my job:**

I sometimes have to deal with government rules and responsibilities that take time away from my research.

**My advice to anyone interested in this occupation:**

Long hours and dedication to your studies now will put you in a good position later, so don’t take the easy road. Follow your dreams and believe in yourself. Even when you think you aren’t good enough for the task ahead of you, be confident. You’ll surprise yourself!

---

Dr. Yvonne Pendleton  
**Astrophysicist**  
NASA Ames Research Center

I think of problems to solve, propose solutions, use the telescope to gather data, analyze the data and present the results in scientific journals and at conferences.

**Areas of expertise:**

- Infrared astronomy
- Star and planet formation
- Interstellar dust
**Research Scientist**

Dr. Michael Kaufman  
Assistant Professor  
San Jose State University

Research Scientist  
NASA Ames Research Center

I make computer models of the chemical and physical makeup of the regions around new stars. Basically, I "teach" the computer how gases near the stars heat up, move, and change. I then compare the computer model to the observations of other scientists to see if they match up. I also teach classes on astronomy at San Jose State University.

**How I first became interested in this profession:**
I liked the space program when I was in grade school. Looking at the stars always fascinated me.

**What helped prepare me for this job:**
Math and physics courses have been a big help for me. Also, good teachers helped prepare me by teaching me how to think and by showing me the kinds of jobs I can have once I got these skills.

**My role models or inspirations:**
I was greatly inspired by my teachers and professors. They had a passion for science, and they loved their jobs.

**My education and training:**
- M.S. and Ph.D. in Astrophysics, Johns Hopkins University
- B.A. in Physics, Middlebury College

**My career path:**
- Researcher at NASA on the National Research Council Fellowship for three years
- Assistant professor at San Jose State University for two years

**What I like about my job:**
I like being able to combine teaching with exploring things that nobody's ever seen before.

**What I don’t like about my job:**
I don’t like the business end of things like faculty meetings and/or anything that takes me away from teaching or research.

**Areas of expertise:**
- The formation of stars

**My advice to anyone interested in this occupation:**
Do well in math and physics. It's easier to do well if it's something you love. You should also be pretty comfortable with computers.
I'm an Engineer. The group I work with does work with both the International Space Station and the Space Shuttle. I'm working on a 3D simulator of one of the labs on the ISS. Scientists will be able to prepare a science experiment, practice it with the simulator, and save it to be used by the astronauts for training. Then the astronauts can show up, watch the scientist's version of the experiment, and practice it themselves. There's also a 2D simulator that they can bring up to the ISS with them. They can use it for review before actually running the experiment. Others in my group are working to improve the docking between the ISS and the Space Shuttle.

Areas of expertise:

- 3D simulation
- Earth Atmosphere Studies
- Astrophysics
- Physics
- Astronomy

How I first became interested in this profession:
When I was in Junior College, I had no idea what to do for a career. I liked English, Shakespeare, Photography, Ceramics, and Math. Science was OK, but not my favorite. One of my friends talked me into taking a basic astronomy course, even though I didn’t need it to graduate. I fell in love with the class (My friend dropped it). I knew after taking that class that I wanted to learn everything I could about Astronomy.

What helped prepare me for this job:
When I finished my Bachelor's Degree, I applied for a job at NASA Ames as a contractor. I was hired by the Earth Science department and worked with a group studying the Earth’s atmosphere. After a couple of years, I applied for a civil servant position (means I work for the federal government rather than a company) as an Engineer at NASA Ames. That was only 6 months ago. I’m still figuring out how to do my new job, and it’s been fun learning a whole new field.

My role models or inspirations:
I have lots of role models. My parents, who taught me the importance of family, and the value of hard work. My sister, because she is one of the most capable people I know. My husband, because he is so easygoing, loves science, and laughs all of the time. Dr. Adrienne Cool, an astrophysicist, has been one of my role models for years. She helped me learn how to do research, which is a lot different from studying books about science. It’s also much more fun. Dr. Tim Castellano is an astronomer I know. He came back to college and became an astronomer after he’d already had a career in a different field. Dr. Yvonne Pendleton is an excellent astronomer at NASA Ames. She spends a lot of time teaching children about astronomy, which I believe is just as important as learning astronomy for yourself.

My education and training:
- B.S. in Astrophysics, San Francisco State University
- Engineering Studies at Stanford University

My career path:
- Contractor, working on Earth’s Atmosphere Studies at the Earth Science Department, NASA Ames Research Center
- Aerospace Engineer at NASA Ames, working on a 3D experiment simulator for the International Space Station (ISS)

My advice to anyone interested in this occupation:
Adrienne Cool has a sign above her desk at San Francisco State University that says: "Think, think, read, think, read, think." This is what it takes to understand and do science. Also, choose a career that you love. Have you heard that before? Probably, but that’s because many people don’t follow the advice and then regret it. There are parts of science that I find really hard, but I always stuck with it. Mostly because I love it, and also because I’m super-stubborn.
Dr. Ed Prather  
Research Scientist with the Conceptual Astronomy and Physics Education Research (CAPER) Team  
University of Arizona

The main focus of my work is on the topic of astrobiology—the search for life in the universe. Over the last two years, I worked at Montana State University as the NASA CERES Astrobiology Project Coordinator. This summer I moved to Tucson, Arizona, where I now work as a Research Scientist for the Conceptual Astronomy and Physics Education Research (CAPER) team in the Department of Astronomy at the University of Arizona. I spend the majority of my time teaching courses, conducting research into student beliefs and learning difficulties, and on developing new activities to help students learn about astronomy and physics.

**Areas of expertise:**
- Astronomy & Physics Education Research
- Physics, Earth & Space Science Curriculum and Course Development
- Faculty/Teacher Professional Enhancement Programs
- K-14 Public Outreach
- Online Course Development and Instruction

**How I first became interested in this profession:**
As a child and a teenager, I liked taking things apart to learn how they worked. In high school, I focused on auto-shop instead of science and math. I then worked as an auto mechanic, and started racing cars and motorcycles, but soon realized that I could not make a living as a professional racer. In my early twenties I decided to go back to school. I immediately fell in love with physics. I was amazed that there was a subject that described how the entire physical world around me worked. Studying physics helped me understand how my race cars and motorcycles operated. For me, the best part of learning physics was working in groups with other students. Along the way, I also discovered astronomy. My career was set, I was going to get a Ph.D. in Physics and teach.

**What helped prepare me for this job:**
The years I spent working on cars and motorcycles helped prepare me for a career in science. To be successful in repairing machines you must become an expert problem solver. You develop the ability to think of a system in terms of both its separate components and as group of interconnected processes. These skills are tremendously valuable when thinking about the physical relationships studied in physics and astronomy. My experience as a technical writer was also very valuable. Part of being successful in science involves your ability to communicate complex ideas clearly and effectively.

**My role models or inspirations:**
I am inspired by people that have a strong sense of commitment to their beliefs, and who have the passion and will to carry out their dreams. My first physics teacher has always served as my role model for teaching, he was the best. I also admire Leonardo da Vinci, Albert Einstein and Richard Feynman.

**My education and training:**
- AA degree, Bellevue Community College, Bellevue, WA
- B.S. in Physics and Astronomy, University of Washington
- Ph.D. in Physics, University of Maine

**My career path:**
- Three years as technical writer for Genie Industries, Redmond, WA
- Four years as research and lead graduate teaching assistant at the University of Maine, Orono, ME
- Two years as instructor in the Physics Dept. at Montana State University
- Two years as Project Coordinator for NASA CERES Astrobiology Project at Montana State University, Bozeman, MT

**What I like about my job:**
Personal Freedom!! Overall I like everything about my job. I feel lucky to be a scientist. My job provides me with the opportunity to work with a wide variety of intelligent, passionate, and very interesting people, while also having the chance to be creative, and think very deeply about cutting edge topics at the horizon of scientific discovery. For myself, the most exciting and rewarding part of my job is the opportunity to work with students—sometimes as their teacher, and other times as a researcher trying to uncover the difficulties they have when learning about physics and astronomy.

**What I don’t like about my job:**
I find that having to continuously look for funding for my research, takes me away from my work. I would also like to see that more of our national budget is dedicated to educational efforts in science.

**My advice to anyone interested in this occupation:**
Find a topic that excites you, and then pursue your dreams with passion and dedication. Believe in yourself, don’t worry about what other people think, and your dreams can come true.
Kelly Snook
Aerospace Engineer, Planetary Scientist, Project Manager
NASA Ames Research Center

I make computer models of Mars, and then compare them to the actual data that we get from the planet. I also do field work, which means I travel to different parts of the world to carry out my research. I recently traveled to the Canadian Arctic in order to test different ways to explore Mars, with which it shares some similarities. I tried on new space suit designs, and rode around on all-terrain vehicles to simulate being on Mars. Because I am a project manager, I also have to do a lot of organizing and paperwork!

Areas of expertise:
- Mars atmosphere
- Manned Mars exploration

How I first became interested in this profession:
I really wanted to go into music, but I thought success might depend more on how lucky I was, than on how hard I worked. One day, I wrote all the professions I could think of on pieces of paper, and I drew engineering out of a hat. Aerospace Engineering sounded interesting. I decided to stick with it, and that became my job.

What helped prepare me for this job:
Working at NASA while doing my Ph.D. work gave me an idea of what working here would be like; I also met many of the people I’d be working with in the future. Hands-on, and project oriented courses have also been very useful in preparing me to build and design.

My role models or inspirations:
One of my role models was my Ph.D. advisor, who guided me through the process of starting to work here. Another major inspiration is Albert Einstein, who had a balanced approach to science and spirituality. I am also very inspired by my religion, the Baha’i Faith: its teachings of harmony between science and religion have motivated me to do well in my work, and through my work, to make the world a better place.

My education and training:
- Ph.D. and M.S. in Aeronautics and Astronautics, Stanford University
- B.S. in Aerospace Engineering, University of Southern California

My career path:
- Eight years as a research/teaching assistant at Stanford University
- Five years as a consultant at NASA Ames
- Two years as an Aerospace Engineer at NASA Ames
- One year Co-Op at the Aerospace Corporation while an undergraduate

What I like about my job:
I like to think about how my work fits in the greater picture of human endeavor and progress. I also enjoy having a job that is exciting, and inspiring, and which allows me the freedom to do what interests me, and the flexibility to do it how and when I want to.

What I don’t like about my job:
I don’t like spending hours filling out forms, or doing other things that take me away from the task I’m here to do. Looking for the money to support my research, can also be time consuming and frustrating.

My advice to anyone interested in this occupation:
Be persistent. Get a good foundation in math, physics, biology, and geology. Don’t lose sight of the things that inspire you, so you’ll always be motivated to do your job well. Make sure to take public speaking, and technical writing courses, in order to get other people also interested in your work and ideas.
Astro Journal Lesson 1: Unit Introduction

Class/Period:

1. Scientific Question:
What do humans need to survive? Why?

2. Hypothesis/Prediction: What do humans need to survive? Why?

3. Materials: List the title, author, date and URL (if applicable) of each resource you used to find your Data.

4. Data: List elements that humans need to survive and explain why? (List only those elements that you can support with evidence from a reputable book, CD-ROM, Web site or other resource.)

Name:

Date:
6. Results: What do humans need to survive? Why? (Create a revised list below based on what you learned from other members in the class and the Human Requirements Reading.)

7. Conclusions: Compare and contrast your predictions and results. How did conducting research change your original ideas?
Human Requirements Reading

Humans have a few basic needs for survival. These include energy sources (food, plants, the Sun), nutrients, water, oxygen and a moderate temperature. Humans also need protection from poisonous gases and high levels of radiation.

Food gives us energy. When we eat food, some components of food are broken down into sugar for energy. Our bodies use the sugar to make the energy we need to move and grow. Energy allows all of our organs to function, allows us to move, talk, run, think, breathe and do all of the things we do every moment. Food for humans is like electricity for a computer. Without electricity, a computer cannot do anything. Without energy, our bodies cannot do anything.

We cannot gain our energy directly from the Sun, so we have to eat plants that gather their energy from the Sun. Animals also gain their energy from plants, so we can also gather energy by eating animals. Therefore, humans need plants and the Sun’s energy to survive.

Nutrients from food build and mend our bones, teeth, nails, skin, hair, flesh and organs and allow us to grow. We need to have a well-balanced diet in order to have all of the nutrients that our body needs.

We can’t get energy from sugar without oxygen. When we breathe oxygen, it is carried throughout our body in the bloodstream to all parts of the body and into the cells where energy is made.

Humans need an average of two quarts of water a day. Our bodies are 60-70 percent water. Water is in our blood, our cells, our tissues and body fluids. Water allows nutrients to circulate throughout the body and allows the body to filter out waste and poisons. Water also allows the body to regulate its temperature. Without water our bodies become dehydrated. If you have ever run for a long time on a very hot day and became very thirsty, you might have been experiencing a little dehydration. Dehydration can become much worse. For example, sometimes when people have the flu, they can become dehydrated and have to go to the hospital. Humans can survive only about three days without water. In comparison, humans can last thirty days without food.

Humans cannot survive very cold or very hot temperatures. Humans must maintain an average body temperature of 98.6°Fahrenheit/37°Celsius. When our body temperature goes above this, we sweat to cool ourselves down. When our body temperature goes below this, we shiver to generate heat. However, our body cannot correct for very large temperature changes. If we are exposed to very cold temperatures, our bodies lose their heat, and we can die from hypothermia. If we are exposed to very hot temperatures, we can die from heat stroke.
Humans must also be protected from harmful gases and too much radiation. An atmosphere with poisonous gases would kill us. Likewise, we need protection from high levels of radiation that come from the Sun and from exploding stars. We especially need protection from solar flares, because they can be unpredictable and release a lot of radiation. High levels of radiation break down the tissues in plants and animals, causing cancer and eventually death.

Although humans can survive for as long as a year in microgravity, the effects of microgravity on our bodies have led scientists to conclude that gravity is important for normal development and function. Without gravity, our bones and muscles shrink and become weak. We lose bodily fluids and red blood cells needed to deliver oxygen and remove waste throughout the body. Fluids in our ears float, so that we become disoriented and confused, and we experience motion sickness. We do not know the range of gravity that is needed for our bodies to function normally, but too much gravity would also have negative effects on our bodies.

It is interesting to note that some living things can exist with different requirements than humans. There are microbes that can live in extremely cold or extremely hot environments, can obtain their energy from volcanic vents rather than from the Sun or other living things and are able to bear higher levels of ultraviolet radiation than humans.

If we have all of the essential things described in this reading, our bodies can function normally; however, some scientists would argue that this would not be enough. They point out that humans have psychological needs, too. Humans need interaction with other humans, for example. A big problem for astronauts who spent a lot of time on the Mir Space Station was that they missed their families a lot. There are scientists whose entire job is just to design the International Space Station so that it is a pleasant environment for scientists. They look at how to design the structure, select colors that are pleasing and to include plants to make the environment more comfortable for astronauts.

Questions
(Answer on a separate sheet of paper)

1. What are three things humans need?
2. Where does our energy come from?
3. Why do we need oxygen?
4. What would happen to our bodies without water?
5. Why is the temperature of Earth important to human survival?
6. Do all living things need the same things as humans? Explain.
Survival Story

On a separate sheet of paper, write a story about a person whose survival is endangered. Stories must include references to human survival needs:

1. Describe all of the necessary elements for human survival and how each of these elements is threatened.
2. Describe the consequence of not having each element.
3. Describe how the hero faces and overcomes these challenges to find each element that s/he needs.

Your story will be evaluated using the following rubric.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Story clearly and accurately explains all human survival requirements.</td>
</tr>
<tr>
<td></td>
<td>Story has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed explanation.</td>
</tr>
<tr>
<td>3</td>
<td>Story clearly and accurately explains all human survival requirements.</td>
</tr>
<tr>
<td></td>
<td>Story has all required parts, makes specific references to examples, and uses good reasoning in explanations.</td>
</tr>
<tr>
<td>2</td>
<td>Story is not completely clear or accurate in explaining the human survival requirements.</td>
</tr>
<tr>
<td></td>
<td>Story has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.</td>
</tr>
<tr>
<td>1</td>
<td>Story is not clear or accurate in explaining the human survival requirements.</td>
</tr>
<tr>
<td></td>
<td>Story is incomplete, makes few specific references to examples, and uses little or no good reasoning.</td>
</tr>
</tbody>
</table>
## Planetary Comparison Chart

<table>
<thead>
<tr>
<th>Planet</th>
<th>Atmosphere</th>
<th>Mass</th>
<th>Diameter</th>
<th>Density</th>
<th>Liquid Water</th>
<th>Average Temperature</th>
<th>Force of Gravity</th>
<th>Atmospheric Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Earth = 1</td>
<td>(Rozzus) (km)</td>
<td>gm/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Mercury</strong></td>
<td>very little: argon, neon and helium</td>
<td>0.06</td>
<td>4,878 (2,439)</td>
<td>5,430</td>
<td>too hot for surface water</td>
<td>day: 350°C/662°F night -170°C/-274°F</td>
<td>0.38</td>
<td>2.03 x 10⁴</td>
</tr>
<tr>
<td><strong>Venus</strong></td>
<td>carbon dioxide</td>
<td>0.82</td>
<td>12,104 (6,052)</td>
<td>5,250</td>
<td>too hot for surface water</td>
<td>465°C/869°F</td>
<td>0.90</td>
<td>1.41 x 10²¹</td>
</tr>
<tr>
<td><strong>Earth</strong></td>
<td>nitrogen, oxygen</td>
<td>1.00</td>
<td>12,755 (6,378)</td>
<td>5,520</td>
<td>liquid water on the surface</td>
<td>15°C/59°F</td>
<td>1.00</td>
<td>5.33 x 10¹⁸</td>
</tr>
<tr>
<td><strong>Moon</strong></td>
<td>none</td>
<td>0.01</td>
<td>3,476 (1,738)</td>
<td>3,300</td>
<td>no liquid water</td>
<td></td>
<td>0.17</td>
<td>0</td>
</tr>
<tr>
<td><strong>Mars</strong></td>
<td>carbon dioxide</td>
<td>0.11</td>
<td>6,790 (3,395)</td>
<td>3,940</td>
<td>Mars may have once had surface water, but doesn't now. Ice has been detected at the North Pole.</td>
<td>-23°C/-9.4°F</td>
<td>0.39</td>
<td>3.09 x 10¹⁶</td>
</tr>
<tr>
<td><strong>Jupiter</strong></td>
<td>hydrogen, helium</td>
<td>318</td>
<td>142,796 (71,398)</td>
<td>1,314</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-150°C/-238°F</td>
<td>2.53</td>
<td>2.6 x 10¹²</td>
</tr>
<tr>
<td><strong>Saturn</strong></td>
<td>hydrogen, helium</td>
<td>95</td>
<td>120,660 (60,330)</td>
<td>690</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-180°C/-292°F</td>
<td>1.06</td>
<td>4.4 x 10¹²</td>
</tr>
<tr>
<td><strong>Uranus</strong></td>
<td>hydrogen, helium</td>
<td>15</td>
<td>51,118 (25,559)</td>
<td>1,290</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-221°C/-391°F</td>
<td>0.93</td>
<td>7.8 x 10²¹</td>
</tr>
<tr>
<td><strong>Neptune</strong></td>
<td>hydrogen, helium</td>
<td>17</td>
<td>49,528 (24,764)</td>
<td>1,640</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-235°C/-391°F</td>
<td>1.18</td>
<td>7.4 x 10²¹</td>
</tr>
<tr>
<td><strong>Pluto</strong></td>
<td>methane</td>
<td>0.002</td>
<td>2,300 approx. (1,150)</td>
<td>2,030</td>
<td>Any water is frozen as ice.</td>
<td>-220°C/-364°F</td>
<td>0.07</td>
<td>variable</td>
</tr>
</tbody>
</table>

*Any water is frozen as ice.*
Students are introduced to the basic requirements for human survival. Using an online, multimedia module, they change factors of our Solar System and draw conclusions about which factors are necessary for human survival.

Main Lesson Concept: Certain astronomical conditions help to support human survival.

Scientific Question: What astronomical conditions are required for human survival?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Students make changes to our solar system and write descriptive, un-biased observations of the effects of these changes on Earth. | Meets:  
|                                                                             | NSES: A 5-8 #1                                                           |
|                                                                             | ISTE 3, 5                                                                 |
| Students will identify the characteristics of our solar system that are required to allow for human survival.                 | Addresses:  
|                                                                             | 2061: 4B 6-8 #2                                                          |
|                                                                             | 2061: 4A 6-8 #1                                                          |
|                                                                             | NSES: D 5-8 #3                                                            |

Assessment: Write-up in Astro Journal.

Abstract of Lesson: Students predict how human survival requirements are met by characteristics of our solar system and planet. They engage in an online Astronomy Training module in which they make changes to the astronomical conditions of our solar system and observe the effects of these changes on Earth. They then draw conclusions about which astronomical conditions are necessary to support human survival.

Prerequisite Concepts:
- Humans need water, oxygen, food, gravity, a moderate temperature and protection from poisonous gases and high levels of radiation to survive. (Lesson 1)
- The Earth is one of several planets that orbit the Sun. Jupiter is a very large planet approximately ten times the diameter of Earth.
- Scientific observations are detailed descriptions of what can be learned using the senses and scientific instruments. These scientific observations do not include ideas, opinions or speculations about what is being observed.
- A star is a large, hot ball of gases, which gives off its own light.
- A planet is a body that does not give off its own light and is orbiting a star. A planet is generally much smaller than a star and can be made of solid, liquid and/or gas.
- A cause is something that produces an effect or result.
- An astronomical unit (AU) is the average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles.

Major Concepts:
- The following characteristics allow Earth to remain habitable to humans:
  - A yellow star
  - Jupiter in a circular orbit beyond three astronomical units (AU)
  - An Earth-size planet of a mass that is between one-fourth and four times Earth's mass
  - The orbit of the Earth-size planet is in the Habitable Zone
- Maintaining liquid water on Earth at all times is essential to support human life.
**MISCONCEPTION:** A common misconception that students have is that the Sun is not a star but is a planet or other object. To help to address this misconception, ask students what the Sun would look like if it were very far away. Ask them what the North Star or other stars would look like, if we were very close to them. Ask students what the differences are between a planet and star. Ask them what kind of object the Sun is. Help them to see that because the Sun is a ball of gases, it is in fact a star, but it doesn’t look like other stars, because it is very close to us, while other stars are very far away. In fact, the closest star would take us thousands of years to reach if we were travelling in the fastest rocket.

Note to Teacher: Star types, orbits, planet mass and the Habitable Zone are concepts that are all explored and defined in later lessons. In this lesson, students simply need to make good observations about “what” is needed for human survival. Lessons 3-12 will give them the “whys” behind these needs.

**Suggested Timeline** (45-minute periods):
Day 1: Engage and Explore Part 1 Sections
Day 2: Explore Part 2 Section
Day 3: Explain, Extend/Apply and Evaluate Sections

**Materials and Equipment:**
- A class set of Astro Journals Lesson 2: Astronomy Training Module *
- 1 Planetary Comparison Chart for each group
- Astronomy Training Walkthrough (Optional)
- Overhead transparencies of Astronomy Training Screen Shots (Optional).
- 1-30 computers with Internet browser, Internet connection and the Shockwave/Flash Player installed.
- A printer connected to the computers.
- Chart Paper
- Overhead projector
- Headphones for the computers (Optional).

**Preparation:**
- Prepare class sets of Astro Journals.
- Prepare overhead transparencies of Astronomy Training Screen Shots.
- Make copies of Planetary Comparison Charts for each group.
- Download and install Shockwave/Flash Players on computers. Test these at http://astroventure.arc.nasa.gov by clicking “Astronomy Training.”
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
- Pair advanced students with students that may need more guidance.
- Encourage students to talk about what they are learning.

**Advanced Extensions**
Research and report on whether the moon is a necessary astronomical condition for life and why or why not.
Engage (approximately 10 minutes)

1. Review Lesson 1.
   • Question: As members of the Astro-Venture Academy, what is our goal?
     • Answer: Our goal is to find, study and design planets that would be habitable to humans.
   • Question: In the first lesson, what elements did you learn are necessary for human survival?
     • Answer: The elements humans need for survival are: food, gravity, oxygen, water, a moderate temperature and protection from poisonous gases and high levels of radiation.

2. Introduce the purpose of the lesson.
   • Say: Since we know that these elements are necessary for our survival, and our goal is to find and design a habitable planet, then we need to determine which conditions of our star system and planet are most likely to have the elements needed for human survival.

3. Bridge to this lesson.
   • Question: When you look at the other planets in our Solar System, which of the necessary elements are most planets missing?
     • Answer: Most planets do not have oxygen or liquid water, and most have temperatures that are far too extreme for humans.
   • Question: Why do you think the other planets do not have these elements?
     • Answer: (Accept all answers)

4. Present the Scientific Question for this lesson.
   • What astronomical conditions allow for human survival?
   • Tell students that they will be role-playing scientists and using a computer activity to find out which astronomical conditions humans need to survive and why.

Explore Part 1 - (approximately 30 minutes)

1. Help students identify possible astronomical conditions for human survival.
   • Say: In the Astronomy section of Astro-Venture, we will be focusing on the star (like our Sun) and the planets and how these parts of our Solar System interact to give us the conditions we need to survive. We will call these conditions the astronomical conditions.
   • Question: What do you think are some of the characteristics of our Solar System that allow Earth to be habitable to humans?
     • Answer: (Accept all answers. Record these ideas on the board.)
Part 1 Unit Introduction  Astronomy Training Module

- Have students place a star by the appropriate answers that are astronomical conditions as opposed to conditions related to geology, atmospheric sciences or biology. (These might include orbital shape and distance, star type, the mass of planetary bodies, location of a star in its galaxy, types of objects in the Solar System, the presence of moons).
- Tell students that we will focus on conditions that have to do with planetary and atmospheric composition and the flow of matter and energy in other sections of Astro-Venture.

2. Have students record their predictions in the Prediction section of their Astro Journal of the astronomical conditions that they predict are necessary for human habitation on a planet.

3. Introduce students to the Astro-Venture Astronomy Training Module.
- Tell students that they will be engaging in an online activity where they will change aspects of the astronomical conditions of our Solar System and will observe the effects on Earth. They will then draw conclusions about the astronomical conditions needed for human survival.
- Tell students that as they go through this module, they will be Astro-Venture Junior Astronomers, and will be evaluated on how detailed their observations are, and whether they give reasons for the effects they observe. They will be able to use their notes on the Astro Challenge, so they should take thorough notes.
- You may want to model for students an example of a "good observation." Either project from a computer for the class to see or project the Astronomy Training Screen Shots to walk the students through the following. (You will need to click through the introduction to get to this part).
  - Click “Star Type.”
  - Click “Yellow Star.”
  - Click “Play” to see the effect on Earth.
  - Ask students to describe what happened to Earth and why. Record a good example of the kinds of observations you expect from students such as: “The Earth remained habitable.”
  - Click “Enter” to see another scientist’s observation. Stress to students that they do not need to type the exact same thing, but should have the same general idea.
    Note to Teacher: Students can change their answer after they click “Enter.” However, their original answers will be printed in their Astro Journal so that you can see if they are making good, initial observations.
  - Point out to students that when they have completed an observation, the factor, which they have chosen turns purple. They must complete all observations in all four major sections before they can advance to the Astro Challenge section.
  - Click “Red Star.”
  - Click “Play.”
  - Ask students to give a detailed observation such as: “The Earth would grow cold and would be covered with ice and snow, because the Red Star is too cold.”
Explore Part 2 - (approximately 45 minutes)

1. Have students engage in the Astronomy Training Module individually, in pairs, small groups or as a class.
   - Students should visit: http://astroventure.arc.nasa.gov and click "Astronomy Training."

   Note to Teacher: You will need the Shockwave/Flash Player plug-in, which can be downloaded and installed from http://sdc.shockwave.com/shockwave/download/ When tested with grades 5-8, the average completion time for 5th graders was 45 minutes. For 8th graders it was 30 minutes. Also, you will want to have accessibility to a printer, so students can print their Astro Journals at the end of the module. These can be used for evaluation purposes. If you want to take the whole class through the module using one computer, use the Walkthrough as a guide.

Explain (approximately 15 minutes)

1. Have students fill out the Results and Conclusion section of their Astro Journals.

2. Discuss students’ Conclusions.
   - Question: What astronomical conditions did you observe are necessary for human habitation of a planet?
   - Answer: (Record on the board) We need: a yellow star, any Jupiter-size planets in a circular orbit beyond 3 AU, a planet with a mass that is 1/4-4 times the mass of Earth that is orbiting in the Habitable Zone.

   - Question: Why do we need each of these? What happens to the planet otherwise?
   - Answer: (Record the reasons next to each factor)

<table>
<thead>
<tr>
<th>Astronomical Condition</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>A yellow star</td>
<td>To maintain a temperature that is neither too hot nor too cold for liquid water.</td>
</tr>
<tr>
<td>Jupiter-size planet in a circular orbit beyond 3 AU</td>
<td>To prevent any Earth-size planets from being thrown out of their orbit to freeze.</td>
</tr>
<tr>
<td>A planet with a mass between 1/4 and 4 times Earth’s mass</td>
<td>To maintain a temperature that is neither too hot nor too cold for liquid water.</td>
</tr>
<tr>
<td>The Earth-size planet must orbit in the Habitable Zone.</td>
<td>To maintain a temperature that is neither too hot nor too cold for liquid water.</td>
</tr>
</tbody>
</table>

   - Question: What is the common theme of all of these conditions?
   - Answer: They allow for liquid water to be present on a planet.
Extend/Apply  (approximately 15 minutes)

1. Have students apply these astronomical conditions to another planet in our Solar System.
   - Have students choose another planet in our Solar System, and use the Planetary Comparison Chart to describe what astronomical conditions would need to change in order for the selected planet to be habitable. They should record this information in the Creating Habitable Conditions for Other Planets section of their Astro Journals.

Evaluate  (approximately 15 minutes)

1. As a class, have students share their planet and discuss what astronomical changes would be necessary to make it habitable to humans.
   Based on what students know so far, their assessments should include observations that most planets are not in the Habitable Zone or have a mass that is too large or small.

2. Tell students that in the next section they will begin to explore the conditions required for water to be a liquid and to clarify how these conditions help us to maintain this essential element for human survival.

3. Collect Astro Journals and evaluate using the Scientific Inquiry Evaluation Rubric to make sure students are ready for the next lesson.
   In particular, assess students' scientific observations for detail, accuracy, and inclusion of a reason and absence of bias.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding. For this lesson, the chart of astronomical conditions needed for human survival on a planet and why these conditions are necessary should also be posted.
**Astro Journal Lesson 2: Astronomy Training Module**

**Class/Period:**

1. **Scientific Question:**
   What astronomical conditions allow for human survival?

2. **Hypothesis/Prediction:** What astronomical conditions do you think humans need to survive? Why?

3. **Materials:** What source will you use to gather data that will help answer this question?

---

**Part 1**

**Name:**

**Date:**

4. **Data:** The following may be recorded and printed online. However, if you are unable to print from the computer, you may use the following chart to record your observations.

<table>
<thead>
<tr>
<th>Cause</th>
<th>Effect on Earth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blue star</td>
<td></td>
</tr>
<tr>
<td>Yellow star</td>
<td></td>
</tr>
<tr>
<td>Red giant</td>
<td></td>
</tr>
<tr>
<td>Red dwarf</td>
<td></td>
</tr>
<tr>
<td>Jupiter in a circular orbit beyond 3AU</td>
<td></td>
</tr>
<tr>
<td>Jupiter in an elliptical orbit at 1 AU</td>
<td></td>
</tr>
<tr>
<td>Small Earth (less than 1/4 mass)</td>
<td></td>
</tr>
<tr>
<td>Average Earth (1/4 to 4 times mass)</td>
<td></td>
</tr>
<tr>
<td>Large Earth (more than 4 times mass)</td>
<td></td>
</tr>
<tr>
<td>Short of the Habitable Zone</td>
<td></td>
</tr>
<tr>
<td>In the Habitable Zone</td>
<td></td>
</tr>
<tr>
<td>Beyond the Habitable Zone</td>
<td></td>
</tr>
<tr>
<td>Earth in an elliptical orbit</td>
<td></td>
</tr>
</tbody>
</table>
### Part 1: Unit Introduction

**Astronomy Training Module**

---

#### Astro Journal Lesson 2: Astronomy Training Module

<table>
<thead>
<tr>
<th>Class/Period</th>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
</table>

5. **Results:** What astronomical conditions allow for human survival? Why? (Create a revised list below based on what you learned from the Astronomy Training Module.)

6. **Conclusions:** Compare and contrast your predictions and results. How did conducting research change your original ideas?
Astronomy Training Walkthrough

The following is an explanation of each section of Astronomy Training. It offers suggestions for how you might take a whole class through the module, if you only have one computer with the ability to project.

Welcome

• Read the introduction with students. This explains the activity students will be going through to make changes to different features of the Solar System, to observe the effects and to record these effects.

Choose Your Character

• Tell students that they will be role-playing scientists. Read with students about each character and have them choose a scientist they wish to be. Discuss why they chose that character. (Students who are in the same group can role-play the same character so all students in the class can print out badges with their names at the end).
  • Choose your characters, entering the first name of each student.
  • Variation: If you don't want to take the time for each student to choose a character, you could have the class vote on a character to represent the whole class.

Note to Teacher: The names collected are used only so that they can be printed on the badge and Astro Journal at the end. NASA does not collect this information.

What do Humans Need to Survive?

• Have students vote on their predictions, and enter these. Emphasize that in science, scientists begin with a good scientific guess. Students are not expected to know the information at this point, but are just predicting.

Note to Teacher: At the end, students will be able to enter their conclusions and see a comparison of their predictions with other scientists’ findings to receive feedback on what they have learned.

Demo

• Read over the training directions with the class and go through the tutorial. Ask students if they think the “Yellow Star” allows Earth to remain habitable or not and why or why not.

Activity

• Click “Star Type.”
• Click “Yellow Star.”
• Ask students what they predict will happen to Earth.
• Click “Play” to see the effect on Earth.
  Note to Teacher: “Play” can be clicked multiple times to see the effect again.

• Ask students to describe what happened to Earth and why.

• Have students record their observations in their copy of the Astro Journal under Data.

• Call on individuals to share what they wrote and have them type their observations in the Astro Journal on the computer. Ask students if they think a “Yellow Star” allows Earth to be habitable or not and why or why not.

• Record a good example of the kinds of observations you expect from students such as: “The Earth remained habitable.”
• Click "Enter" to see another scientist's observation. Stress to students that they don't need to type the exact same thing, but should have the same general idea.

Note to Teacher: Students can change their answer after they click “Enter.” However, their original answers will be printed in their Astro Journal so that you can see if they are making good, initial observations.

• Point out to students that when they have completed an observation, that factor turns purple. They must complete all observations in all four major sections before they can advance to the Astro Challenge section.

• Click “Red Star.”

• Click "Play."

• Ask students to give a detailed observation such as: "The Earth would grow cold and would be covered with ice and snow, because the Red Star is too cold."

• Explain that a good scientific observation is detailed and describes what is observed.

• Tell students that since they will be able to use their notes when they take the Astro Challenge, they should take thorough notes.

Completion of Activity

• Continue through each "Star Type," "Jupiter's Orbit," "Earth's Mass" and "Earth's Orbit."

• Have the class record their observations in their Astro Journals and then have individuals take turns typing in their observations in the computer.

• Have students record in Astro Journals the results of the changes they observed which resulted in a habitable Earth.

• After all observations have been completed, click "Submit" and take the Astro Challenge as a class.

• Encourage students to go back to the relevant sections and look at their notes in the Data collection chart (located in the Astro Journal section) to help answer the questions.

• Have students vote on the answers.

Conclusion

• Have students vote on the results that they found. Discuss how their results compare to their predictions.

• Print student badges, the class Astro Journal and trading cards, if you wish.
Astro-Venture: Astronomy Educator Guide EG-2002-10-001-ARC

Astronomy Training Module Screen Shots

1. Congratulations!

2. Choose Your Character

3. What Do Human Need to Survive? (Prediction)
4A. Select a feature such as “Star Type” (left menu)
4B. Select a subtopic such as "Yellow Star" to cause a change to our Solar System.
4C. Click "Play" to see the effect on Earth.
4D. Record what you observe in your Astro Journal
Astronomy Training Module Screen Shots

4E. Look in your Tech Notes for background information and a glossary.
Astronomy Training Module Screen Shots

4F. Roll over highlighted words in the Tech Notes for glossary definitions.
Astronomy Training Module Screen Shots

4G. The specialist will give you directions, feedback and help.
4H. Continue using steps 4A-4G for all other features and subtopics and record observations.
4II. When you have completed all of your observations, click the Submit button to take your Astro Challenge and earn your badge.
5. Roll over the letters to view the answers in your Astro Challenge.
Astronomy Training Module Screen Shots

6. Click above the Specialist's picture for hints to help you with your Astro Challenge.
## Planetary Comparison Chart

<table>
<thead>
<tr>
<th>Planet</th>
<th>Atmosphere</th>
<th>Mass (Earth = 1)</th>
<th>Diameter (Radius) (km)</th>
<th>Density (gm/m³)</th>
<th>Liquid Water</th>
<th>Average Temperature</th>
<th>Force of Gravity (Earth = 1)</th>
<th>Atmospheric Mass (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>very little: argon, neon and helium</td>
<td>0.06</td>
<td>4,878 (2,439)</td>
<td>5,430</td>
<td>too hot for surface water</td>
<td>day: 350°C/662°F nght -170°C/-274°F</td>
<td>0.38</td>
<td>2.03 x 10⁸</td>
</tr>
<tr>
<td>Venus</td>
<td>carbon dioxide</td>
<td>0.82</td>
<td>12,104 (6,052)</td>
<td>5,250</td>
<td>too hot for surface water</td>
<td>465°C/869°F</td>
<td>0.90</td>
<td>1.41 x 10²¹</td>
</tr>
<tr>
<td>Earth</td>
<td>nitrogen, oxygen</td>
<td>1.00</td>
<td>12,755 (6,378)</td>
<td>5,520</td>
<td>liquid water on the surface</td>
<td>15°C/59°F</td>
<td>1.00</td>
<td>5.33 x 10²⁴</td>
</tr>
<tr>
<td>Moon</td>
<td>none</td>
<td>0.01</td>
<td>3,476 (1,738)</td>
<td>3,300</td>
<td>no liquid water</td>
<td>sunlit side: 134°C/273°F dark side: -153°C/-243°F</td>
<td>0.17</td>
<td>0</td>
</tr>
<tr>
<td>Mars</td>
<td>carbon dioxide</td>
<td>0.11</td>
<td>6,790 (3,395)</td>
<td>3,940</td>
<td>Mars may have once had surface water, but doesn't now. Ice has been detected at the North Pole.</td>
<td>-23°C/-9.4°F</td>
<td>0.39</td>
<td>3.09 x 10²⁴</td>
</tr>
<tr>
<td>Jupiter</td>
<td>hydrogen, helium</td>
<td>318</td>
<td>142,796 (71,398)</td>
<td>1,314</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-150°C/-238°F</td>
<td>2.53</td>
<td>2.6 x 10²⁰</td>
</tr>
<tr>
<td>Saturn</td>
<td>hydrogen, helium</td>
<td>95</td>
<td>120,660 (60,330)</td>
<td>690</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-180°C/-292°F</td>
<td>1.06</td>
<td>4.4 x 10²²</td>
</tr>
<tr>
<td>Uranus</td>
<td>hydrogen, helium</td>
<td>15</td>
<td>51,118 (25,559)</td>
<td>1,290</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-221°C/-391°F</td>
<td>0.93</td>
<td>7.8 x 10¹¹</td>
</tr>
<tr>
<td>Neptune</td>
<td>hydrogen, helium</td>
<td>17</td>
<td>49,528 (24,764)</td>
<td>1,640</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-235°C/-391°F</td>
<td>1.18</td>
<td>7.4 x 10¹¹</td>
</tr>
<tr>
<td>Pluto</td>
<td>methane</td>
<td>0.002</td>
<td>2,300 approx. (1,150)</td>
<td>2,030</td>
<td>Any water is frozen as ice.</td>
<td>-220°C/-364°F</td>
<td>0.07</td>
<td>variable</td>
</tr>
</tbody>
</table>
Astro Journal

Embarking on an Astronomy Astro-Venture!

By: ________________________________ (your name)
### Astro Journal

<table>
<thead>
<tr>
<th><strong>Scientific Question:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Hypothesis/Prediction:</strong> What do you predict and why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Materials:</strong> What materials will you use to investigate?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Procedure:</strong> List the steps you will take to investigate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 2:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 3:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 4:</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Step 5:</td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

### Name:

<table>
<thead>
<tr>
<th><strong>Data Collection:</strong> Record and display your data in a chart, table, picture or graph.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Results:</strong> Summarize what your data mean.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Conclusions:</strong> Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction change your original ideas?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
Scientific Inquiry Evaluation Rubric For Evaluating Astro Journal Entries

<table>
<thead>
<tr>
<th>Component</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis/Prediction</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Specific enough to be testable/observable and give a meaningful result</td>
</tr>
<tr>
<td></td>
<td>• Has basis in solid information or observations and a logical reasoning process</td>
</tr>
<tr>
<td>Materials, Procedures,</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td>and Data</td>
<td>• Complete</td>
</tr>
<tr>
<td></td>
<td>• Accurate and tied directly to hypothesis and scientific question</td>
</tr>
<tr>
<td>Results</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to Scientific Question and data</td>
</tr>
<tr>
<td></td>
<td>• Draws a reasonable conclusion from that data</td>
</tr>
<tr>
<td>Conclusions</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• States how hypothesis/prediction was confirmed and/or altered</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to findings, observations, and/or data to explain why thoughts were changed.</td>
</tr>
</tbody>
</table>

Scores:
4: Expectations Exceeded
3: Expectations Met
2: Expectations Not Quite Met
1: Expectations Not Met
Part 2: States of Matter
Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature is not a measure of heat but of the average motion of molecules of a substance.

**Main Lesson Concept:** Matter can exist in three states: solid, liquid and gas. Each state has unique properties.
(Note to Teacher: A fourth state of matter, plasma, is beyond the scope of this lesson.)

**Scientific Question:** What are the similarities and differences between the properties of solids, liquids, and gases?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will identify the properties of solids, liquids and gases and will cite similarities and differences in those properties.</td>
<td><strong>Meets:</strong> NSES: B K-4 #1</td>
</tr>
<tr>
<td></td>
<td><strong>Addresses:</strong> NSES: A 5-8 #1</td>
</tr>
</tbody>
</table>

**Assessment**
Write-ups and illustrations of the three states of matter in Astro Journal.

**Abstract of Lesson**
Students observe samples of solids, liquids and gases. They then find similarities and differences among the properties. They record their findings and conclusions in their Astro Journals.

**Prerequisite Concepts**
- Volume is the amount of space an object takes up.
- Shape is a particular form.
- Molecules are the smallest individual parts of a substance.
- Matter is anything that has mass and volume or anything that takes up space.

**Major Concepts**
- A solid has a definite shape and volume.
- A liquid has a definite volume but not a definite shape.
- A gas has no definite shape or volume.
- Solids, liquids and gases take up space.
**Suggested Timeline** (45 minute periods):
Day 1: Engage and Explore Sections
Day 2: Explain, Extend and Evaluate

**Materials & Equipment:**
- Reclosable plastic bags with solids, liquids and gases (one set for each group). Include thick solids such as blocks, and thin solids such as potato chips or crackers, viscous (thicker) liquids such as toothpaste or honey, and less viscous liquids such as water. You may use air as your only gas. All samples should be small enough to fit in a cup.
  - Cups (1 or 2 per group)
  - Balloons (1 or 2 per group)
  - A class set of Astro Journals Lesson 3: Properties of Matter*
  - A class set of Astro Journal covers
  - A class set of Scientific Inquiry Evaluation Rubric

**Preparation:**
- Gather materials.
- Make reclosable plastic bags with each object or substance for groups.
- Prepare Astro Journals.
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs:
- Have students give an oral report of their Astro Journal entry.
- Emphasize the visual component of their response.

**Advanced Extensions**
For students who have mastered this concept:
- Have students research and report on Plasma – the fourth state of matter.
- Have students research and report on why dry ice goes from a solid to a gas?

Note to Teacher: Dry ice is solid CO₂. It cannot exist as a liquid under Earth’s normal pressure conditions. Advanced students can, thus, start to investigate that pressure is also a factor in states of matter.
1. **Discussion: Review of Part 1**
   - Question: In the Astronomy training module, what did you determine to be the essential element for sustaining human life?
   - Answer: Liquid water. (This is the answer you’re looking for. Acknowledge other correct responses.)

2. **Going over lesson purpose with students**
   Since we know we need liquid water to sustain human life, we need to understand a little more about what liquid water is and the conditions that allow us to have liquid water.

3. **Bridging to this lesson**
   - Question: Can water be in another state or form besides liquid?
     - Answer: Yes. As a solid, it’s called ice. As a gas, it’s called vapor.
   
   - Question: What states can matter be in?
     - Answer: Solid, liquid or gas.
     Note to Teacher: Plasma is also a state of matter, but is beyond the scope of this lesson.

4. **Present Scientific Question for lesson:**
   What are the similarities and differences among the properties of solids, liquids, and gases?

5. **Tell students that they will be observing and testing samples of matter in order to answer that question.**

---

**Engage** *(approximately 20 minutes)*

**Explore** *(approximately 25 minutes)*
5. Data collection: (Teacher Demonstration)
   • Hold up a solid and ask students if it is a solid, liquid, or gas. Ask them to record the name of the object and the state of matter on their chart in the Data Collection section of Astro Journal Lesson 4.
   • Demonstrate different ways to test the object to see if its shape changes easily. Try bending it, putting your finger through it, putting it in another container, etc. Ask students if the shape is easily changed. Have them record this observation on their Astro Journal chart.
   • Demonstrate different ways to test the object to see if it takes up space. Put the object in a container such as a cup. Ask students if the object takes up space. Have them record this observation on their Astro Journal chart.
   • Demonstrate different ways to test the object to see if its volume changes easily by pouring it out of the container. Ask students if the amount of space taken up (volume) is the same as when the object is not in the container. Have them record this observation on their Astro Journal chart.

6. Data Collection: (Student Exploration)
   • Have students observe the other solids, liquids, and gases with their groups and mark their charts in the same way for each.
   • They should also record the test materials in their Materials section.

1. Review data collection activity (especially if this is a separate class from Engage and Explore sections).
   • Question: What are the three states of matter we have been working with?
     • Answer: Solid, liquid, and gas.
   • Question: What rules did we use to test our samples of matter?
     • Answer: We tested whether it has a fixed shape, a fixed volume, and whether it takes up space.
   • Question: What are the similarities and differences among the properties of solids, liquids, and gases? (Scientific Question)
     • Elicit some sample responses from people and record key ideas on the board/overhead/chart paper. Question any incorrect or imprecise responses.
       A solid has a definite shape and volume.
       A liquid has a definite volume but not a definite shape.
       A gas has no definite shape or volume.
       Solids, liquids, and gases take up space.
MISCONCEPTION: Students may not really understand or believe that a gas takes up space. To test:

- Question: How do you know that the air is taking up space?
  - Answer: Allow students to share their ideas about this. Answers may include: We can see clouds. When we blow up a balloon, air fills it. Birds and airplanes can glide because of air.

- Question: How do we know that there is air around us?
  - Answer: We breathe. We can feel the wind blowing, etc.

- Blow up a balloon.
- Question: What is inside the balloon?
  - Answer: Air.

- Question: What is causing the balloon to expand and hold its shape?
  - Answer: Air.

- Question: How does this show us that air takes up space?
  - Answer: The air is the only thing in the balloon which could be giving it its expanded shape.

2. Go over the rubric for Journal entries with students.

3. Students fill in the Results section of the Astro Journal.

Extend/Apply  (approximately 15 minutes)

1. Reconnect with lesson purpose.
   - Question: What do we know now about liquid water that makes it different from solid water (ice) and gaseous water (steam, vapor, clouds, fog)?
   - Answer: Liquid water has a fixed volume, but not a fixed shape.

2. Have students illustrate and label the three states of water in the Illustrations section of their Astro Journals.
Evaluate (approximately 10 minutes)

1. **Have students fill out the Conclusion section in their Astro Journals.**
   Emphasize the importance of referring directly to their testing experience in explaining how they either changed or confirmed their hypothesis.

2. **Have students share their illustrations.**
   - Review the characteristics of solids, liquids and gases.
     - A solid has a definite shape and volume.
     - A liquid has a definite volume but not a definite shape.
     - A gas has no definite shape or volume.
   - Have students identify drawings completed by their classmates that show the characteristics of each state of matter.
   - Have students explain how the drawings clearly illustrate each state.

3. **Collect Astro Journals and evaluate using the Scientific Inquiry Evaluation Rubric to make sure students are ready for the next lesson.**

   Note to Teacher: After each lesson, consider posting the main concept of the lesson someplace in your classroom. As you move through the unit, you and your students can refer to the “conceptual flow” and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
### Astro Journal Lesson 3: Properties of Matter

**Class/Period:**

<table>
<thead>
<tr>
<th>1. Scientific Question:</th>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the similarities and differences among solids, liquids, and gases?</td>
<td>Date:</td>
</tr>
</tbody>
</table>

|-----------------------------------------------------------------|-------------------------------------------------|

For each sample:
- Record the type of matter. (Solid, Liquid, or Gas)
- Does it take up space? (Yes or No)
- Does it have a fixed volume? (Yes or No)
- Does it have a fixed shape? (Yes or No)

<table>
<thead>
<tr>
<th>3. Materials: What materials will you use to investigate?</th>
<th></th>
</tr>
</thead>
</table>
### 5. Data Collection: Record and display your data in a chart.

<table>
<thead>
<tr>
<th>Solid, Liquid, Gas?</th>
<th>Fixed shape?</th>
<th>Fixed volume?</th>
<th>Take up space?</th>
<th>Sample</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 6. Results: What are the similarities and differences among solids, liquids, and gases? Describe and illustrate.

### 7. Conclusions: Compare and contrast your predictions and results. How did testing your hypothesis/prediction change your original ideas?
Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

**Main Lesson Concept:** The properties of matter derive from the bonds between the molecules and the motion of the molecules that make up the matter.

**Scientific Question:** Why do the states of matter have the properties that they have?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will explain and illustrate that the properties of matter derive from the connections between molecules.</td>
<td><strong>Meets:</strong> 2061: 4D 6-8 #3 NSES: B 9-12 #1</td>
</tr>
<tr>
<td>Students will demonstrate their learning on a poster.</td>
<td><strong>Addresses:</strong> NSES: A 5-8 #1</td>
</tr>
</tbody>
</table>

**Assessment**

Astro Journal; poster of Molecules of Matter.

**Abstract of Lesson**

Students use their bodies to model the connections between molecules in the three states of matter. They then create a poster that illustrates and explains these connections.

**Prerequisite Concepts**

- A solid has a definite shape and volume. (Lesson 3)
- A liquid has a definite volume but not a definite shape. (Lesson 3)
- A gas has no definite shape or volume. (Lesson 3)
- An object with a fixed shape will either keep its shape or break into pieces.
- A substance with a fixed volume will always take up the same amount of space.

**Major Concepts**

- A molecule is the smallest part of a substance and is composed of one or more smaller parts.
- Molecular bonds are the forces that hold molecules together.
- Molecular motion is the movement of molecules.
Suggested Timeline (45-minute periods):
Day 1: Engage, Explore, and Explain Sections
Day 2: Extend Section
Day 3: Evaluate Section

Materials and Equipment:
- A class set of Astro Journals Lesson 4: Matter and Molecules*
- Paper and art materials (colored pencils, markers, paints, etc.) for posters
- A class set of Storing and Transporting Matter
- A class set of Molecules and Matter Poster

Preparation:
- Gather materials.
- Duplicate Astro Journals, Storing and Transporting Matter and Molecules and Matter Poster.
- Prepare classroom. (Make sure there’s room for the molecular modeling activity in step 3 of Explore.)
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations
For students who may have special needs:
- Have a partner help write the caption for the poster.
- Have them give an oral report of Storing and Transporting Matter activity

Advanced Extensions
For students who have mastered this concept:
- See Advanced Extensions in Lesson 3.
- Research and report on the relationships among atoms, elements, and molecules.
- Research and report on how molecular bonds work.

---

### Engage (approximately 10 minutes)

1. **Review states of matter and their properties**
   - Question: What are the three states of matter we’ve been working with and what are their properties?
   - Answer: A solid has a definite shape and volume. A liquid has a definite volume but not a definite shape. A gas has no definite shape or volume. Solids, liquids, and gases take up space.

2. **Go over Scientific Question with students.**
   - Scientific Question: Why do the states of matter have the properties that they have?

3. **Record student responses on board/overheard/chart paper.**
   - Students record their predictions in the Hypothesis/Prediction section of their Astro Journals.

---

### Explore (approximately 25 minutes)

1. **Discussion: Introducing molecules and molecular bonds**
   - Question: What is the smallest possible unit of a substance?
   - Answer: Molecules. (This is the answer you’re looking for.)
     - Note to Teacher: Students may respond with “atoms” or “elements.” For a substance that is an element, such as gold or lead, an atom is the smallest unit. For all other substances (ones that are made up of more than one element), the molecule is the smallest unit of that substance.

   - Question: What holds molecules together?
   - Answer: Molecules are held together by bonds between the molecules called molecular bonds.

2. **Check that students understand molecules and molecular bonds.**

3. **Activity: Students will act as “molecules” of a substance in the three states of matter.**
   - Have students first try to figure out the bonds between molecules.
   - Question: If a solid has a fixed shape and a fixed volume, what do you think the bonds are like between the molecules, and how could you model this?
   - Answer: The bonds are strong in a solid.
     - Note to Teacher: Students should be standing somewhat close together with their hands or wrists linked. They should be vibrating, but not moving around.

   Make any corrections to the students’ model and explain that even solid matter is made up of atoms and molecules that are moving.

   - Question: If a liquid does not have a fixed shape but does have a fixed volume, what do you think the bonds are like between the molecules, and how could you model this?
   - Answer: The bonds between molecules are weaker, allowing the molecules to slide past each other.
     - Note to Teacher: Students should now be moving around, but still touching as they pass each other.
Make any corrections to the students' model, and emphasize that the molecular bonds of a liquid are weaker than the bonds of a solid.

- **Question:** How do the properties of solids and liquids compare with the bonds between those states?
  - **Answer:** Solids have a fixed shape and have strong bonds between their molecules, which limit movement to vibration. Liquids do not have a fixed shape, and their bonds are weaker allowing the molecules to slide past each other.

- **Question:** If a gas does not have a fixed shape or a fixed volume, what do you think the bonds between the molecules are like, and how could you model this?
  - **Answer:** The bonds are no longer strong enough to hold the molecules together.
  
  **Note to Teacher:** The students are moving freely. They should be moving around a little more quickly than when they were liquid, and they should be spread out, rarely encountering each other.

Make any corrections to the students' model and emphasize that the bonds are no longer strong enough to hold the molecules together.

- **Question:** How do the properties and bonds of a gas compare with the properties and bonds of solids and liquids?
  - **Answer:** Both solids and liquids have a fixed volume while a gas does not. Both solids and liquids have bonds that are strong enough to keep connections with the molecules. The bonds in a gas are too weak to do so.

**Explain** (approximately 10 minutes)

1. Go over the rubric for Journal entries with students.
   **Note to Teacher:** The Astro Journal for this lesson is a little different because the students are not performing an experiment but rather building a model of molecules with teacher direction and assistance.


3. Students respond to the Scientific Question in the Results section of the Astro Journal.

**Extend/Apply** (approximately 45 minutes)

1. Review *Properties of Matter and Molecules* (especially if starting a new class period).
   - **Question:** What are the properties of the states of matter and the molecular bonds that determine them?
     - **Answer:**
       - **solid:** fixed volume, fixed shape, strong molecular bonds limiting movement to vibration of molecules
       - **liquid:** fixed volume, no fixed shape, weaker molecular bonds allowing molecules to slide past each other
       - **gas:** no fixed shape or volume, extremely weak molecular bonds allowing molecules to move freely
2. **Introduce Storing and Transporting Matter activity**  
   (student activity sheet and rubric are included with the Lesson 4 Astro Journal.)

   - **Question:** What are some of the liquids that we commonly use?  
     - **Answer:** *(Record on the board.)* Answers may include: water, milk, juice, soda pop, gasoline, medicines such as cough syrup, etc.

   - **Question:** What solid items do we commonly use?  
     - **Answer:** *(Record on board.)* Answers may include: cereal, crackers, vitamins, video tapes, pencils, notebooks, etc.

   - **Question:** What gases do we commonly use?  
     - **Answer:** *(Record on board.)* Answers may include: natural gas is often used for heating homes or to power certain appliances. Air conditioning and refrigerators use gas. We might use steam or water vapor to help relieve congestion for a cold.

   - Say: In the following activity, you will apply what you know about how solids, liquids and gases differ to decide how best to store and transport them.

   - Highlight the importance of using students' knowledge of matter and molecular bonds to affirm their system for storing and transporting the matter.

3. **Have students complete the Storing and Transporting Matter activity.**

4. **Have students share and discuss their work.**

   - **Question:** What are some considerations you made for storing solids?  
     - **Answer:** Solids have a fixed shape, so it's best if solids can be stacked or contained in rectangular boxes that can be stacked.

   - **Question:** What considerations did you make for liquids?  
     - **Answer:** Liquids don't have a fixed shape, so they can easily be contained in a stackable container; however, the container must not have any holes for liquid to escape.

   - **Question:** What considerations did you make for gases?  
     - **Answer:** Gases have no fixed shape or volume, so they must be contained in airtight containers.
Evaluate (approximately 45 minutes—higher quality posters may take more time)

1. **Students create a poster that shows the bonds between molecules in the three states of matter.**
   The assignment is included with the Astro Journal for this lesson. The assignment also includes the evaluation rubric.
   - Go over the rubric and expectations with the students. Inform them that they will be self-evaluating their posters when they are done.
   - Note to Teacher: You may choose to include their self-evaluation as a part of their grade.

2. **Students create their posters.**

3. **Students fill in the Poster Self-Evaluation section of their Astro Journals.**

4. **Students fill in the Conclusion section of their Astro Journals.**

5. **Students share and discuss their posters.**
   - Have students look at their classmates’ poster and identify good examples of each state of matter.
   - Have students explain how the drawings clearly illustrate each state and molecular bonds of each state.

Note to Teacher: After each lesson, consider posting the main concept of the lesson someplace in your classroom. As you move through the unit, you and your students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
### Astro Journal Lesson 4: Molecules and Matter

<table>
<thead>
<tr>
<th>Class/Period:</th>
<th>1. Scientific Question: Why do the states of matter have the properties that they have?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2. Hypothesis/Prediction: Why do you think the states of matter have the properties that they have?</td>
</tr>
<tr>
<td></td>
<td>3. Materials: What materials were used to model molecular bonds and motion?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
</table>

| 4. Procedure: How did the model work? |
### Astro Journal Lesson 4: Molecules and Matter

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Class/Period:</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>5. Data Collection:</th>
<th>Record and display your data in a chart, table, picture or graph.</th>
</tr>
</thead>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name:</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Date:</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>6. Results:</th>
<th>Why do the states of matter have the properties that they have?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>7. Conclusions:</th>
<th>Compare and contrast your predictions and results. How did modeling the molecular bonds and motion change your original ideas?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Illustrations:**

- Diagrams
- Photographs
- Graphs
Activity: Storing and Transporting Matter

Human beings have many uses for matter in all three states. We build things (buildings, tools, and consumer items) out of solids. We consume liquid water, and we use liquid gasoline to power our cars as well as liquid oil to keep the engines running smoothly. Many of our homes are heated with gas (natural gas, propane), and many refrigerators and air conditioning units use some kind of gas as a part of their systems.

For this reason, we need to be able to effectively store and transport matter in all three states. To do so properly, we need to use our knowledge of the properties of the states of matter and of molecular bonds. For example, because of their strong molecular bonds, solids have a fixed shape and a fixed volume. The actual shape of the matter, then, becomes an important factor in designing storage and transportation for it. This is not necessarily the case with gases and liquids.

Assignment:
1. Choose a solid, a liquid, and a gas that humans use on a regular basis.
2. Explain the significance of the substance for humans.
3. Describe and illustrate a system for storing and transporting the matter.
4. Explain how your system deals with the properties of the matter and its molecular bonds. (In other words, how does your system take advantage of the properties and/or overcome the limitations of the properties?)

Your work will be evaluated using the following rubric:

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Explanations and illustrations are clear and accurate.</td>
</tr>
<tr>
<td></td>
<td>Explanation of storage/transport system shows a strong connection to the properties and molecular bonds/movement of the matter.</td>
</tr>
<tr>
<td>3</td>
<td>Explanations and illustrations are clear and accurate.</td>
</tr>
<tr>
<td></td>
<td>Explanation of storage/transport system shows a connection to the properties and molecular bonds/movement of the matter.</td>
</tr>
<tr>
<td>2</td>
<td>Explanations and illustrations are not completely clear or accurate.</td>
</tr>
<tr>
<td></td>
<td>Explanation of storage/transport system shows some connection to the properties and molecular bonds/movement of the matter.</td>
</tr>
<tr>
<td>1</td>
<td>Explanations and illustrations are not clear or accurate.</td>
</tr>
<tr>
<td></td>
<td>Explanation of storage/transport system shows little or no connection to the properties and molecular bonds/movement of the matter.</td>
</tr>
</tbody>
</table>
Assignment: Molecules and Matter Poster

Create a poster that shows the bonds between the molecules and the movement of the molecules in the three states of matter. Your poster should include a caption (or captions) that describe the connections as well as an explanation of the motion. Your poster will be evaluated using the following rubric. Your score will be the number which best describes your work.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The bonds in the three states of matter are accurately, creatively, and effectively portrayed in the illustration and explained concisely and effectively in the captions. Elements of the poster are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make the poster exceptionally clear and easy to understand.</td>
</tr>
<tr>
<td>3</td>
<td>The bonds in the three states of matter are clearly and accurately portrayed in the illustration and explained in the captions. Elements of the poster are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make the poster easy to read and understand.</td>
</tr>
<tr>
<td>2</td>
<td>The illustration and explanation of the bonds in the three states of matter are not completely clear or completely accurate. Elements on the poster could be better spaced, and design elements (color, lines, shapes, and content illustrations) make the poster a little difficult to read.</td>
</tr>
<tr>
<td>1</td>
<td>The bonds in the three states of matter are unclear or inaccurate in the illustration and/or the caption. Elements of the poster are either squashed together or large spaces are empty, and design elements (color, lines, shapes, and content illustrations) make the poster difficult to read.</td>
</tr>
</tbody>
</table>

Poster Self-Evaluation

Evaluate your performance using the rubric. Give yourself a score and then explain why you think the work deserves that score. Make references to specific parts of your poster when explaining your score.
Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

**Main Lesson Concept:** Matter changes state when temperature changes.

**Scientific Question:** What causes matter to change its state and how is this accomplished?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Students will use an inquiry process to identify temperature as the variable that causes a substance to change from one state to another. | **Meets:** 2061: 4D 6-8 #3  
NSES: B 9-12 #5  
NSES: A 5-8 #1  
**Addresses:** NCTM: 4, 5, 9 |
| They will then identify the relationship between temperature and the molecular bonds and movement in a substance. | |
| Students will explain the temperature conditions of a planet necessary for human life. | |

**Assessment**
Write up of inquiry experience in Astro Journal, Test on Part 2: States of Matter.

**Abstract of Lesson**
Students use an inquiry process to determine what causes matter to change state. When they have learned that temperature is the cause, they recreate their physical modeling of molecules and molecular bonds and explore what happens to matter as temperature increases and decreases.

**Prerequisite Concepts**
- A solid has a definite shape and volume. A liquid has a definite volume but does not have a definite shape. A gas has no definite shape or volume. (Lesson 3)
- Molecular bonds are the forces that hold molecules together. Molecular motion is the movement of molecules. (Lesson 4)
- Students should have experience with graphing and applying the correct type of graph for the data that is being represented. A pie chart shows parts of a whole. A line graph shows change over time. A bar chart shows a comparison of amounts.

**Major Concepts**
- Temperature is the variable that causes matter to change state.
- Matter tends to expand as temperature increases and to contract when temperature decreases. Water is an exception to this rule.
**Suggested Timeline** (45 minute periods):
Day 1: Engage and Explore Part 1 Sections
Day 2: Explore Part 2 and Explain Sections
Day 3: Extend/Apply and Evaluate Part 1 Sections (30 minutes)
Day 4: Evaluate Part 2

**Materials and Equipment:**
- A class set of Astro Journals Lesson 5: Changing States of Matter*
- A class set of Scientific Inquiry Evaluation Rubric
- A class set of States of Matter Test
- Thermometers (approximately 1 for every 3 to 4 students)
- Miscellaneous supplies that students need for the experiments they design (make list after Explore Day 1)
- Chart paper

**Preparation:**
- Gather materials (e.g., thermometers, miscellaneous supplies).
- Duplicate a class set of Astro Journals, Scientific Inquiry Evaluation Rubric Sheets and States of Matter Test
- Prepare classroom: (Make sure there's room for the molecular modeling activity in Extend/Apply).
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs, use a more guided inquiry process.

**Advanced Extensions**
Have students conduct research or an inquiry experiment on the following question: How does pressure affect the molecular bonds and state of matter?

Engage  (approximately 15 minutes)

1. Review Lesson 4
   • Question: What are the properties of the states of matter and the molecular bonds which determine their properties?
   • Answer:
     • Solids have a fixed volume, a fixed shape and strong molecular bonds limiting movement to vibration of molecules.
     • Liquids have a fixed volume, no fixed shape and weaker molecular bonds allowing molecules to slide past each other.
     • Gases have no fixed shape or volume and weak molecular bonds allowing molecules to move freely.

2. Bridge to this lesson.
   • Question: What are the differences between the molecular bonds in solids, liquids, and gases?
   • Answer: Molecular bonds are strongest in solids and weakest in gases.

   • Question: What are the differences between the movement of the molecules in solids, liquids, and gases?
   • Answer: The molecules in solids only vibrate. In liquids, the molecules slide past each other. In gases, the molecules spread out freely.

   • Question: How do the strengths of the molecular bonds relate to the movement of the molecules?
   • Answer: As the movement of the molecules increases, the strength of the molecular bonds decreases. 
     Note to Teacher: This is true of the bonds between molecules, not the bonds between atoms.

   • Question: What could cause the bonds between the molecules to be weaker or stronger?
   • Answer: (The students will probably not be able to answer this. Record their responses if they have some).

   • The question in another form is the Scientific Question for this lesson.
   • Say: We now understand the difference between solids, liquids, and gases, but in order to know what will allow a planet to have the conditions needed for liquid water, we need to understand what causes this change.

3. Introduce Scientific Question and purpose of the lesson.
   • Say: The scientific question that we will be exploring is, “What causes matter to change its state and how is this accomplished?”
   • Question: Why do we want to know what causes matter to change state?
   • Answer: This will help us to understand the conditions that we need to have liquid water on a planet.

4. Tell students that they will be conducting experiments and making observations to answer this question.
Explore Part 1 - (approximately 30 minutes)

1. **Elicit some hypotheses from the students.**
   
   Go over expectations for hypotheses from the inquiry rubric and model how to revise a hypothesis to improve it (i.e. make it clearer, testable, more specific, etc.).
   
   Note to Teacher: Based on your experience with your class, there are at least 3 ways to proceed from here. Students who would benefit from the opportunity to design their own experiment should do so. If the class is not ready as a whole, you can also do this as a whole-class project in which everyone contributes to one hypothesis and test. You could also work with a group who needs more assistance while allowing those who would benefit to work on their own to do so.

2. **Put students into groups to refine hypotheses and plan experiments to test them.**
   
   Have students record their Hypothesis/Prediction section of their Astro Journals.

3. **Further model for students how to create a “test” for the hypothesis and demonstrate how the Materials, Procedures, and Data for the test will be recorded in the Astro Journal for this lesson.**
   
   Note to Teacher: Make sure that the students are thinking in terms of data – what data they will be collecting how they will be measuring it, and how that it is either going to confirm or refute their hypotheses.

4. **Give students some time to put together their Materials and Procedures list in order to figure out what data they will be collecting and how they will measure it.**
   
   Instruct students to fill out the Procedure section of their Astro Journal.

5. **Have students share their hypotheses, and experiment plans.**
   
   Ask questions to help groups clarify aspects of their plan, but try to avoid giving them the answers.
   
   - **Sample Questions:**
     - How does this experiment test your hypothesis?
     - What specific data are you collecting?
     - How will this data confirm or refute your hypothesis?
     - How are you going to measure your data?
   
   Note to Teacher: Corrections should be focused on science process, not the accuracy of the hypothesis. An incorrect hypothesis with a solid experimental plan is fine. A correct hypothesis without a solid experimental plan should be corrected.

6. **Ask students for a list of materials they will need to conduct their experiments.**
Explore Part 2 - (approximately 25 minutes)

1. Have students review their hypotheses and experiment plans and then conduct their experiments.

2. Students perform their experiments and collect their data.
   Students record data in the Data section of their Astro Journals.

   (Sample Experiment: Many students will identify temperature and heat as the essential factor. One way, to test this would be to use ice, water, and containers that can be heated. Provide some type of heat source, and thermometers for measuring temperature. The experiment could proceed by measuring the initial temperatures of the samples, and then taking a series of measurements over time as heat is increased. Follow all safety instructions with whatever heat source you and your students use.)

Explain (approximately 20 minutes)

1. Instruct students to organize their data into a chart or graph in the Charts and Graphs section of their Astro Journal.
   Note to Teacher: You may want or need to do a formal introduction about or review of graphing. Most likely some kind of line graph indicating temperature change over time will be the best way to present the information.
   • Students may need some assistance in choosing the most appropriate way to graph their data.
   • Sample Questions:
     • How does this graph either support or refute your hypothesis?
     • Is there any other kind of graph that might better show what the data demonstrates about your hypothesis?

2. Ask some groups to share their hypotheses, data, and what they think their data demonstrates about their hypotheses and what we can learn from each individual experiment and the experiments as a whole.

MISCONCEPTION: Many students may feel that if their hypothesis is not “right” then their experiment is a failure. Emphasize that this is not true. Scientific understanding grows when we eliminate incorrect answers to scientific questions. The success or failure of a hypothesis and experiment is based on the accuracy of the process, not the result. Either way, we learn something.
Extend/Apply  (approximately 15 minutes)

1. Have students recreate the molecular bonding modeling that they did in Lesson 4.
   - Students begin as a solid (locked tight - vibrating only).
   - Say: O.K., now we're raising the temperature. We're turning up the heat. What's happening to the matter?
   - Students should start loosening their connections and moving past each other while continuing to keep contact.

   - Say: Now we're really turning up the heat. The temperature is rising more and more. What's happening to the matter?
   - Students should be moving more quickly and independently.

   - Raise and lower the 'temperature' and have the students adjust their physical model.

2. Have students observe what happens to the size of the group of molecules (i.e. the students) as the temperature is raised and lowered.
   - Question: As the temperature raises and the matter changes from solid to liquid, then liquid to gas, how does the amount of space that the matter is taking up change?
   - Answer: As the temperature increases, the matter expands and takes up more space.

   - Tell the students that when a substance starts to take up more space, we say it is “expanding”.

   - Question: As the temperature lowers and the matter changes from gas to liquid, then liquid to solid, how does the amount of space that the matter is taking up change?
   - Answer: As the temperature decreases, the matter contracts and takes up less space.

   - Tell the students that when a substance starts to take up less space, we say it is “contracting”.

   Note to Teacher: The terms ‘expand’ and ‘contract’ will be used in the reading assignment for Lesson 6. Making sure that these concepts are understood will help with that reading.

PROBLEM: There is problem at this point in the lesson, which must be explained. Water is an exception to this tendency. When ice forms, it actually expands (hence experiences such as pipes bursting when frozen in winter and ice cubes rising above the level of the water that was put into the ice tray). There is little way around this since our focus is on water, but the standard requires learning the more general principle. This peculiarity of water derives from the hydrogen bonds in water that form into a special structure that causes the water (ice) to expand. Some students may point this out or you may want to point this out to your students. As the teacher, you're in the best position to know how to introduce this information to your students.
Evaluate Part 1 - (approximately 15 minutes)

1. Have students fill out the Results and Conclusion sections in their Astro Journals. Emphasize the importance of referring directly to their testing experience and their modeling of molecular bonds.

2. Discuss the students' results.
   - Question: What did you observe causes matter to change its state and how is this accomplished?
   - Answer: Temperature changes states of matter by increasing or decreasing the motion of the molecules and causing changes in the molecular bonds.

Evaluate Part 2 - (approximately 45 minutes)

1. Review Lesson 4 and Connect to Lesson 1: Unit Introduction
   - Review the requirement for human survival that students explored in Lesson 1:
     - food (plants in particular)
     - water
     - oxygen
     - moderate temperature (average global temperature of less than 50° Celsius.)
     - protection from high levels of radiation
     - other requirements the students found
   - Question: If the average temperature of the Earth were lower, what would happen to any liquid water which was present?
     - Answer: The water present would freeze.
   - Question: What would happen to the Earth's ability to support life?
     - Answer: Earth's ability to support life would be reduced, if not eliminated.
   - Question: If the average temperature of the Earth were higher, what would happen to any liquid water?
     - Answer: The liquid water would boil away.
   - Question: What would happen to the Earth's ability to support life?
     - Answer: Earth's ability to support life would be reduced, if not eliminated.

2. Part II Evaluation
   - Give the States of Matter test (found at end of Astro Journal).

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the 'conceptual flow' and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
## Astro Journal Lesson 5: Changing States of Matter

<table>
<thead>
<tr>
<th>Class/Period:</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Scientific Question:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What causes matter to change its state and how is this accomplished?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>2. Hypothesis/Prediction:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What do you think causes the change? Why?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>3. Materials:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What materials will you use to test your hypothesis or prediction?</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>4. Procedure:</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Astro Journal Lesson 5: Changing States of Matter

<table>
<thead>
<tr>
<th>Class/Period:</th>
<th></th>
</tr>
</thead>
</table>

5. **Data Collection**: Record and display your data in a chart, table, picture or graph.

<table>
<thead>
<tr>
<th>Charts/Graphs:</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Date:</td>
<td></td>
</tr>
</tbody>
</table>

6. **Results**: What causes matter to change its state and how is this accomplished?

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

7. **Conclusions**: Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the molecules change your original ideas?

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
# States of Matter Test

**Name:**

**Directions:** Answer the following questions in complete sentences. Make sure to clearly explain your ideas and use specific examples. Include illustrations or other visual information to help with your responses.

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Explain and illustrate the different states of matter and their properties (such as shape and volume) in terms of the strength of the bonds between molecules and how the molecules move.</td>
<td>Illustrations:</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Explain and illustrate what happens to bonds between molecules and to the motion of molecules as the temperature increases. Use a solid as the starting point.</td>
<td>Illustrations:</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>3. What temperature requirements must a planet have in order to support human life?</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
States of Matter Test - Correction and Scoring Guide

1. Explain and illustrate the different states of matter and their properties (such as shape and volume) in terms of the strength of the bonds between molecules and how the molecules move.

   Solids have strong molecular bonds and little molecular motion. The molecules only vibrate. That’s why they retain their shape and volume. Liquids have weaker molecular bonds, which allow for more motion. The molecules can slide past each other. This is why liquids do not retain their shape. The molecules can slide around each other to fit whatever is containing them. However, they do maintain the same volume. Gases have very weak bonds, which allow for great molecular motion. In fact, gas molecules rarely encounter each other. This is why gases do not have a fixed volume or shape. They can spread out until they are contained by something. All three states of matter take up space.

2. Explain and illustrate what happens to bonds between molecules and to the motion of molecules as the temperature increases. Use a solid as the starting point.

   As the temperature increases, the molecules move faster. For example, as the molecules in a solid warm up, the molecular bonds start to loosen and the molecules start moving faster. As they are able to slide past each other more easily, the solid becomes a liquid. As the temperature keeps increasing, the molecules move faster and faster. Eventually, they are moving fast enough to break free of each other. At this point the liquid becomes a gas.

3. What temperature requirements must a planet have in order to support human life?

   There are many possible answers here. Evaluate the responses according to the strength of the student’s reasoning and his or her use of examples. The most important part is that the temperature must be within a range that allows water to be liquid at all times. Too cold will not work, because water will freeze. Too hot will not work, because water will evaporate.

Scoring the Test:
A simple way to score the test is the following. Each question can be worth 5 points for a total of 15 points possible. Assign scores to each question based on accuracy, completion, and use of specific examples. The chart below has a sample table to convert the scores to rubric scores or grades. You may use this or come up with your own scoring system. You may also adjust to include plus or minus grades.

<table>
<thead>
<tr>
<th>Test Score</th>
<th>Rubric Score</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>15, 14, 13</td>
<td>4</td>
<td>A</td>
</tr>
<tr>
<td>12, 11, 10</td>
<td>3</td>
<td>B</td>
</tr>
<tr>
<td>9, 8, 7</td>
<td>2</td>
<td>C</td>
</tr>
<tr>
<td>&lt;7</td>
<td>1</td>
<td>D or F</td>
</tr>
</tbody>
</table>
Students explore the conditions required for water to be in a liquid state. They discover that temperature is the essential variable. They then explore how temperature affects the motion of molecules and molecular bonds.

**Main Lesson Concept:** Temperature is a measurement of the movement of atoms and molecules in a substance. It is measured by thermometers using various temperature scales.

**Scientific Question:** What does temperature actually measure and how do we measure it?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will identify that temperature measures the movement of molecules in a substance.</td>
<td><strong>Meets:</strong> 2061: 4D 6-8 #3 NSES: B 9-12 #5 <strong>Addresses:</strong> NSES: A 5-8 #1 NCTM: 4</td>
</tr>
<tr>
<td>Students will identify the thermometer as the tool and the Fahrenheit, Celsius, and Kelvin scales as the means by which we measure temperature.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Abstract of Lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write-ups in Astro Journal.</td>
<td>Students apply their knowledge of how temperature affects matter to understand how a thermometer works. They then read about the history of the thermometer and the temperature scales that make the information from the thermometer meaningful.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisite Concepts</th>
<th>Major Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Scale is a set of ordered marks on a measuring instrument, usually with numbers in equal or fixed increments.</td>
<td>• Temperature measures the motion of molecules in a substance.</td>
</tr>
<tr>
<td>• Molecular bonds are the forces that hold molecules together. (Lesson 4)</td>
<td>• Thermometers have a liquid inside that expands when heated.</td>
</tr>
<tr>
<td>• Molecular motion is the movement of molecules. (Lesson 4)</td>
<td>• Celsius, Fahrenheit and Kelvin are different temperature scales.</td>
</tr>
</tbody>
</table>
**Suggested Timeline** (45 minute periods):
Day 1: Engage and Explore Sections
Day 2: Explain and Evaluate Sections

**Materials and Equipment:**
- A class set of Astro Journals for Lesson 6: Measuring Temperature*
- A class set of Measuring Temperature reading
- Thermometers (approximately one for every three to four students)
  
*Note to Teacher: Digital thermometers will not work for this activity
- Water samples (hot and cold tap water)

**Preparation:**
- Duplicate Astro Journals Lesson 6 and Measuring Temperature Reading.
- Gather materials
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs, provide extra support for the reading assignment (e.g. partner, read aloud, etc.).

**Advanced Extensions**
- Have students perform conversions between temperature scales.
- Have students explain how the freezing point of water is used to help convert among the Fahrenheit, Celsius, and Kelvin temperature scales.
- Research and Report on how a thermometer is calibrated.
1. Heat is the kinetic energy (or movement) of all molecules in a system. Temperature is the measure of the average kinetic energy (or movement) of the molecules of a system. People tend to think of temperature in terms of "hot" and "cold". The problem with this is that "hot" and "cold" need some reference points in order to have value. The temperature of 101 degrees Fahrenheit (F) may be a "hot" day (to some people), but it would be too "cold" to do most kinds of baking or cooking in an oven. What we as people experience as "hot" and "cold" are actually experiences of heat transfer. Heat tends to transfer from where there is a higher temperature to where there is a lower temperature. On that same 101° F day, the temperature of the air around us is higher than our own temperature (98.6° F) so we experience warmth and call the day, "hot".

- Questions that can help bring out this misconception are: What is heat? What is temperature? What does it mean to be hot? How could you explain heat in terms of the motion of molecules?

- For students struggling with this idea, consider the following activity (you’ll need warm and cold water - both samples safe to touch). Choose a test object in the classroom that should be at room temperature. Have the student put her or his hand in the cold water and then touch the test object. Because the hand has been cooled, the student should experience the object as "warm". The student should then put his or her hand in the warm water and then touch the test object. Because the hand has been warmed, the student should experience the object as cool. The temperature of the object hasn't changed only the student's perspective on it.

- Heat transfer can also be modeled physically. Think about billiard balls or marbles. If two balls that are moving at different speeds hit each other, the faster one will slow down and the slower one will speed up. Put students into two groups: one that is "warmer" (moving more quickly) and one that is "cooler" (moving very slowly). Have the two groups mix. As a "warmer" molecule bumps a "cooler" molecule, the warmer one slows down (becomes cooler) while the cooler one speeds up (becomes warmer). Make sure that the students are not too "enthusiastic" when making contact with each other.

2. People sometimes refer to the heat "in" an object, the heat "in" the air or the heat "in" us. This implies that the object is a container for the heat. This is not really true. When heat transfers from one object to another, the movement of the atoms and molecules of the first object slow down (on average) while the movement of the atoms and molecules of the second substance speed up (on average). This transfer will occur until the atoms and molecules in both objects are moving at the same average speed. The heat, then, is not "in" the object but is a quality "of" the object. To demonstrate this understanding, it is more accurate to refer to the heat "of" a substance. This is not to suggest that you mechanically correct students who say "in" as opposed to "of", but rather that you consider that a student who persistently uses "in" might not truly understand what heat is and how it relates to molecular bonds and motion.

3. When we touch an object that has a lower temperature, heat transfers from us to the object and we experience that object as "cold". Because the experience of "cold" is as real as the experience of "hot", people tend to think of "cold" as being a type of energy in the same way that heat is a form of energy. For example, students might think that refrigerators and air conditioners are devices that create cold energy. In truth, these devices work by removing heat energy just as our experience of a "cold" object is the experience of heat from us transferring to the object.

- For students who don't believe this, have them find a refrigerator or air conditioner and find the part of the device that vents the heat.
1. Review Lesson 5.
   • Question: What causes matter to change state and how does it do so?
   • Answer: Temperature causes the change by changing the movement of the molecules and the strength of the molecular bonds.
     Note to Teacher: This is true for the molecular bonds between the molecules, not the atomic bonds holding each individual molecule together.

2. Bridge to this lesson.
   • Question: So if raising temperature causes molecules and atoms to move more, and lowering temperature causes molecules and atoms to move less, what is temperature really measuring?
   • Answer: The movement of the molecules and atoms. The students may also respond with ‘heat’.

   • Question: So what does heat have to do with temperature?
   • Answer: Heat is the energy that causes the molecules and atoms to move. Temperature is the measurement of heat.

   • Question: What about cold? What does it have to do with temperature?
   • Answer: Cold is a word used to describe something that has less heat energy (i.e. less molecular motion) than whatever it is being compared with.

   • Question: Do objects that are ‘cold’ have any heat in them at all?
   • Answer: Yes, just less than whatever it is being compared with.

3. Introduce the purpose of the lesson.
   • Question: When do we measure temperature and why?
   • Answers may include: We measure heat outside to decide what to wear or to be prepared for ice or snow. We measure the temperature of the refrigerator to make sure that food doesn’t go bad. We measure the temperature of the oven so that we can bake food evenly. We measure the temperature of our bodies to see if we have a fever. Measuring temperature allows us to have a common language to compare temperatures accurately such as the temperature of Los Angeles with the temperature of New York.

   • Say: So there are many uses for measuring temperature, since we know that at certain temperatures substances do different things, and we want to be prepared for those changes or we want to control them.

   • Question: Thinking about our habitable planet, how might measuring temperature be useful in determining what will make our planet habitable to humans?
   • Answer: By measuring the temperatures that the human body can stand, we can tell what our limits are for temperatures that are too hot or cold. These limits give us a good idea of the temperature range needed for human survival. If we then measure the temperature of a planet or moon, we can tell if its temperature falls in this range.

   • Say: Since measuring temperature is so important in science, we are going to look at how this is done.

4. Introduce the Scientific Question for the lesson:
   • What does temperature actually measure and how do we measure it?
   • Students record their predictions in the Prediction section of their Astro Journals.

Explore (approximately 30 minutes)

1. **Engage students in an exploration of how a thermometer works.**
   - Depending on your class, you may want to give a hint – it involves a small change in the movement and the bonds of the substance in the thermometer (most likely alcohol in a school thermometer).
   - Ask students the Exploration question and have a few predict a response orally (How does a thermometer work?).
   - Pass out thermometers and samples of hot and cold water to groups.
   - Have students use the thermometers in the water samples and closely observe what happens.
   - Elicit some sample responses and view some illustrations. If the students are not making the connection to a changing state of matter, give them the hint or ask, Could a change in the motion of molecules and molecular bonds have anything to do with how a thermometer works?
   - Students record their observations and create illustrations in the Exploration section of their Astro Journals.
   - Have students discuss in their small groups what they wrote and illustrated. Then have a spokesperson from each group share what the group agreed upon as their explanation. Help students to provide reasoning for their explanations.

   **Note to Teacher:** Students should conclude that the water molecules are moving more quickly than the molecules of the substance in the thermometer. The movement of the molecules of the water cause the molecules of the glass to start moving more quickly which causes the molecules of the substance in the thermometer to move more quickly which causes the substance to expand.

Explain (approximately 30 minutes)

1. **Have students complete the Measuring Temperature reading.**

2. **Have students complete the questions for the reading in their Astro Journals.**
   Discuss with students different temperature scales, when each is useful in science and what they are based upon.
1. **Discuss students' results.**
   - **Question:** What does temperature actually measure?
     - **Answer:** Temperature measures the movement of atoms and molecules in a substance.
   - **Question:** How do we measure temperature?
     - **Answer:** We use a thermometer to measure temperature. The liquid inside of the thermometer expands when it becomes hotter and contracts when it becomes cooler. The amount that it expands or contracts is measured with a certain scale: Celsius, Fahrenheit or Kelvin.

2. **Have students fill out the Results and Conclusion sections in their Astro Journals.**
   Emphasize the importance of referring directly to their testing experience in explaining how they either changed or confirmed their hypothesis.

3. **Discuss student responses to ensure that they have mastered these concepts.**
   - **Question:** What does temperature actually measure?
     - **Answer:** Temperature measures the movement of molecules in a substance.
   - **Question:** How do we measure temperature?
     - **Answer:** We use thermometers and the scales of Celsius, Fahrenheit or Kelvin. Thermometers have a liquid inside that expands when heated.

4. **Collect Astro Journals and evaluate using the Scientific Inquiry Evaluation Rubric.**
   Focus on students understanding of temperature as the measurement of the motion of molecules and the use of thermometers and different scales to measure temperature.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
Astro-Venture: Astronomy Educator Guide

Part 2


Name: ____________________________ Date: ____________________________

4. Exploration: How does a thermometer work? Record your observations and illustration below.

Astro Journal Lesson 6: Measuring Temperature

1. Scientific Question: What does temperature actually measure and how do we measure it?

2. Hypothesis/Prediction: What do you think temperature actually measures and how do we measure it?

3. Materials: What materials will you use to investigate?
5. Questions from reading: Carefully read the questions and respond using complete sentences.

Why is measurement important in science?

What qualities does mercury have that makes it a good substance to use in a thermometer? What do these qualities have to do with molecular motion and bonds?

How did Anders Celsius create his temperature scale?

What is absolute zero and what does it have to do with the motion of molecules?

6. Results: What does temperature actually measure? How do we measure temperature?

7. Conclusions: Compare and contrast your predictions and results. How did modeling the molecular bonds and motion change your original ideas?
Measuring Temperature Reading

“When you can measure what you are speaking about and express it in numbers, you know something about it.”

Lord William Thomson Kelvin (1824-1907)

There are two requirements for taking a measurement of something. The first is a tool for taking a measurement. The second is scale for making sense of the numbers of the measurement. For example, a ruler is often used to measure short lengths. It is the tool for measurement. On the ruler are one or more number scales with equally spaced numbers. These numbers can be compared with numbers from any other ruler that is accurately set to the same scale. Measuring length is far simpler than measuring temperature. While there is evidence of tools for measuring length at various times in human history, tools and scales for measuring temperature do not appear until more recent human history.

Early thermometers, called thermoscopes, first appear in the 1500’s. They were crude instruments that were not at all accurate. Most did not even have a number scale associated with them. This made them useless for most practical purposes. Gabriel Fahrenheit created the first accurate thermometer in 1714, and the Fahrenheit temperature scale followed it in 1724. The thermometer’s accuracy was based on its use of mercury, a silver colored substance that remains liquid over a wide range of temperatures but expands or contracts in a standard, predictable way with changes in temperature. To set the scale, Fahrenheit created the coldest temperature that he could. He mixed equal parts of ice, water, and salt, and then used this as the zero point, 0 degrees, of his scale. He intended to make 30 degrees the freezing point of water and 90 degrees the temperature of the human body, but he had to later revise these temperatures to be 32 degrees and 96 degrees. In the final version of the scale, the temperature of the human body became 98.6 degrees.
In 1742, Anders Celsius recommended that the scale on the mercury thermometer be adjusted so that 100 degrees occurred at the freezing point of water and 0 degrees occurred at the boiling point of water. The range between the boiling and freezing points were divided into 100 equal parts. For this reason, the scale was first called the Centigrade scale (‘centi’ being the prefix for one hundredth). He also made the measurement of those key points more precise. The scale did not become truly popular until after Celsius’s death when the measurements for the freezing and boiling points were switched. 0 degrees was set at the freezing point of water, while 100 degrees became the boiling point of water. In 1948, the Centigrade scale became officially known as the Celsius scale in honor of its creator.

The Celsius scale is the most commonly used temperature scale in the world today, but it is not the best scale for every use. Certain formulas used to predict weather do not work if the number for temperature is a negative number. Since the temperature of the air can easily be lower than the freezing point of water, scientists need a different scale. The scale they use is called the Kelvin scale, named for Lord William Thomson Kelvin who created it in the mid-1800’s. Kelvin was able to calculate the coldest that anything in the universe could ever be. This became the zero point of his scale. 0 Kelvins is 273 degrees on the Celsius scale. It is also the temperature at which molecules and atoms have the least possible motion. For this reason, 0 Kelvins is also called “absolute zero.” There can be nothing colder.
Astro Journal

Embarking on an Astronomy Astro-Venture!

By: ____________________________ (your name)
**Astro Journal**

<table>
<thead>
<tr>
<th>Scientific Question:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypothesis/Prediction: What do you predict and why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Materials: What materials will you use to investigate?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Procedure: List the steps you will take to investigate.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1:</td>
</tr>
<tr>
<td>Step 2:</td>
</tr>
<tr>
<td>Step 3:</td>
</tr>
<tr>
<td>Step 4:</td>
</tr>
<tr>
<td>Step 5:</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Data Collection: Record and display your data in a chart, table, picture or graph.</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Results: Summarize what your data mean.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction change your original ideas?</th>
</tr>
</thead>
<tbody>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------</td>
</tr>
</tbody>
</table>
## Scientific Inquiry Evaluation Rubric for Evaluating Astro Journal Entries

<table>
<thead>
<tr>
<th>Component</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis/Prediction</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Specific enough to be testable/observable and give a meaningful result</td>
</tr>
<tr>
<td></td>
<td>• Has basis in solid information or observations and a logical reasoning process</td>
</tr>
<tr>
<td>Materials, Procedures,</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td>and Data</td>
<td>• Complete</td>
</tr>
<tr>
<td></td>
<td>• Accurate and tied directly to hypothesis and scientific question</td>
</tr>
<tr>
<td>Results</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to Scientific Question and data</td>
</tr>
<tr>
<td></td>
<td>• Draws a reasonable conclusion from that data</td>
</tr>
<tr>
<td>Conclusions</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• States how hypothesis/prediction was confirmed and/or altered</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to findings, observations, and/or data to explain why thoughts were changed.</td>
</tr>
</tbody>
</table>

**Scores:**

4: Expectations Exceeded
3: Expectations Met
2: Expectations Not Quite Met
1: Expectations Not Met
Part 3: Astronomical Factors
Lesson 7: Thinking in Systems

Students explore the planetary temperature system. They further explore how each part influences the system and the consequences of disrupting that system.

Main Lesson Concept: Systems consist of many parts. The parts usually influence each other. A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or disconnected. Thinking about things as systems means looking for how every part relates to other parts. Any system is usually connected to other systems.

Scientific Question: What are the characteristics of a system?

| Objectives                                                                 | Standards           |
|словы  | | |
| Students will explain: how a system is made up of interacting parts, that when parts of the system change it affects the system, and that systems are often related to other systems. | Meets:  
2061: 11A 3-5 #1, #2  
2061: 11A 6-8 #2, #3  
NSES: UCP K-12 #1  
Addresses:  
NSES: A 5-8 #1 |

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Abstract of Lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write-ups in Astro Journal.</td>
<td>Students explore the characteristics of systems in terms of the human body. They then choose another system to explore and create a concept map of this system. Finally, they summarize the characteristics of a system.</td>
</tr>
</tbody>
</table>

Prerequisite Concepts

- Most things are made of parts.
- Something may not work if some of its parts are missing.
- In a system when parts are put together, they can do things that they could not do by themselves.

Major Concepts

- A system consists of many parts that usually influence each other and can be part of another system.
**Suggested Timeline** (45 minute periods):
Day 1: Engage and Explore Sections
Day 2: Extend and Evaluate Sections

**Materials and Equipment:**
- A class set of Astro Journals Lesson 7: Thinking in Systems*
- Chart paper/overhead projector/board

**Preparation:**
- Duplicate a class set of Astro Journals Lesson 7: Thinking in Systems
- Prepare chart paper or overhead projector to record student responses
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs, provide physical systems for students to explore such as a stereo system or a model car that can be taken apart to have its system explored.

**Advanced Extensions**
Investigate non-physical systems such as processes that accomplish a goal. Create a concept map of a process and show how the characteristics of a system relate to a process.
   • Question: Now that we've finished Part 2, what is an essential factor or variable in determining whether or not a planet can have water in a liquid form on its surface?
   • Answer: An essential variable needed to determine if a planet could have water in liquid form, would be temperature.
   
   • Question: Why is temperature an essential variable?
   • Answer: If the temperature of the planet is too low, the water will freeze. If the temperature of the planet is too high, the water will boil away.
   
   • Question: Remind me, why are a moderate temperature and liquid water important?
   • Answer: We need a moderate temperature and liquid water to survive.

2. Bridge to this lesson.
   • Question: What causes a planet to have the temperature that it does?
   • Record responses on the board/chart/overhead.
   • Have the students discuss and evaluate the responses.

   • Question: Which of these ideas are likely causes for the temperature of a planet and why?
   • Answer: Have the students explain their reasons. Accept all reasonable answers.

   • Question: Which one of these ideas is most likely the cause of temperature on a planet?
   Note to Teacher: Yes, this is a trick question.
   • Answer: There is no single cause for the temperature of a planet. There are many variables, which affect the temperature of a planet.
   • Say: There are many variables, which affect the temperature of a planet. No single one of them is enough to affect the temperature of a planet. In later lessons, we'll be looking at the essential variables that affect the temperature of a planet.

3. Introduce the Scientific Question and purpose of the lesson.
   • Say: In order to understand how different variables work together in a system, we need to better understand the characteristics of a system. The scientific question that we will be exploring is "What are the characteristics of a system?"
   • Say: We're going to be looking at other situations like the planetary temperature system where different parts of a system work together. This will help us to better understand systems and how systems relate to supporting human life.
• Create a concept map of the human body as an example of a system.
• Question: What are some of the parts of the human body that help keep you alive?
  • Answer: samples - The brain, heart, lungs, veins, arteries, nerves, etc.
• Record student responses on board/overhead/chart paper.
  Note to Teacher: Clustering/webbing/concept mapping might be a good way to record student responses.

```
Brain

Heart

Body

Lungs
```

• Question: Is there any one of these parts that could keep you alive without the others?
  • Answer: No. All of these parts are needed to keep us alive.
• Question: Are these parts separate, or do they work together?
  • Answer: All these parts work together.
• Question: Let's be more specific. How does the heart work with the veins and arteries?
  Note to Teacher: The goal of Steps 3 – 7 is to have the students discover the characteristics of systems from the national education standards by thinking about the human body as a system. You may substitute different parts of the body if you think your students will know those better, or you may substitute another system if you think that would be more appropriate.
  • Answer: The heart pumps blood through the veins and arteries.
• Question: How does the brain work with the rest of the body?
  • Answer: The brain tells the rest of the body what to do by sending messages through the spinal column and nerves.
  • Say: All of the parts of the body work together, and no single one of the parts could keep you alive without the others. When there is a situation in which there are several parts to something that have to work together to accomplish a task or to make a product or outcome, we call it a system. We’re going to explore some characteristics of systems.
1. **Explore the first characteristic of a system:**
   In systems that consist of many parts, the parts usually influence each other.
   
   - Inform students that they will be thinking about the temperature of a planet as a system in later lessons.
   - Question: Based on what we have learned so far, what would you say is an important characteristic of systems?
     - Answer: An important characteristic of a system is that the parts work together.
   - Question: If parts are working together, does that mean that they could be influencing or affecting each other?
     - Answer: Yes, the parts could be influencing or affecting each other.
   - Question: How does the heart affect or influence the brain?
     - Answer: The heart pumps blood to the brain so that the brain can survive.
   - Question: How does the brain affect or influence the heart?
     - Answer: The brain tells the heart when to beat.
   - Have students explain this characteristic and brainstorm other examples of systems. Possible systems might include science systems such as a body system (nervous, respiratory, digestive, etc.) or an ecosystem; social systems such as the government system or justice system; mechanical systems such as a car, a factory or a clock.
   - Have them draw a concept map of a chosen system and its parts in their Astro Journals.

2. **Explore the second characteristic of a system:**
   Something may not work as well (or at all) if a part of the system is missing, broken, worn out, mismatched or misconnected.
   
   - Question: Could a person live if something happened to his heart and it stopped beating?
     - Answer: No. He couldn’t live unless something was able to start it again.
   - Question: Could a person live if her lungs were so severely damaged that they were no longer able to work?
     - Answer: No, a person could not live if her lungs were severely damaged.
   - Question: What would happen if a person’s veins or arteries became more and more clogged?
     - Answer: If a person’s arteries became clogged the blood would have a harder time flowing. If the arteries kept getting clogged, the person would probably die.
   - Question: What would happen if the brain were suddenly no longer connected to the rest of the body?
     - Answer: The body would die if the brain were no longer connected to the rest of the body.
   - Question: Based on these examples, what could we say about systems?
     - Answer: A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected.
   - Have students explain this characteristic by describing the effects of one part of their chosen system being damaged or taken away in their Astro Journals.
3. **Explore the third characteristic of a system:**
   Thinking about things as systems means looking for how every part relates to each other.
   
   - **Question:** Let’s think about one part of the system: the heart. How does the heart relate to the arteries and veins?
   - **Answer:** The heart pumps blood through the arteries and veins.
   
   ![Concept Map with Blood Vessels, Heart, Brain, Body, Lungs, Valves, and Pump]

   - **Question:** How does the heart relate to the lungs?
   - **Answer:** The heart pumps blood to the lungs so that the blood can get oxygen.

   - **Question:** How does the heart relate to the brain?
   - **Answer:** The heart pumps blood to the brain which needs oxygen to survive.

   - **Question:** If we chose another part of the body, could we find ways to relate that part to other parts of the body?
   - **Answer:** Yes, we probably could find ways to relate that chosen part of the body to other parts of the body.

   - **Question:** Based on these examples, what could we say about systems?
   - **Answer:** Thinking about things as systems means looking for how every part relates to others.
   - **Answer:** Have students explain this characteristic by explaining how the parts of their chosen system relate to each other in their Astro Journals.

4. **Explore the fourth characteristic of a system:**
   Any system is usually connected to other systems.
   
   - **Question:** If we think of the human body as a system that keeps a person alive, does that system ever come into contact with other systems? If so, what might those other systems be?
   - **Answer:** Yes, humans contact other people, each of whom is a separate system.

   - **Question:** Could people be parts in a larger system?
   - **Answer:** Yes, people could be parts of a larger system.

   - **Question:** What are some examples of systems that have people as parts?
   - **Answer:** Some examples of systems are families, school systems, justice systems, government systems, etc.
• Question: Let’s use the school as an example. What are the different types of people in a school?
• Build on the previous concept map of the human body to show how this is a sub-system of another system.
• Answer: The different types of people in a school are teachers, students, and the principal.

• Discuss the role of the principal in regards to a system

• Question: How would you say that the people in a school affect or influence each other?
• Answer: The principals set the goals. The teachers teach the students based on the goals set by the principal. And the students learn from teachers.

• Question: Would the system work, if we took one group of people away?
• Answer: No, the system would not work, if we took one group away.

• Question: Based on these examples, what could we say about systems?
• Answer: Many systems are usually connected to other systems.

• Have students explain this characteristic by building on their concept map to show how it is a subsystem of another system in their Astro Journals.
Extend/Apply  (approximately 30 minutes)

1. Engage students in an activity on other examples of systems.
   • Review the characteristics of systems and how they apply to individual people as systems, and groups of people as systems.
   • Have students design their own system that fulfills some important function such as making breakfast and explain how the characteristics of a system are displayed by the system.

Evaluate  (approximately 15 minutes)

1. Discuss the characteristics of systems.
   • Have students share their chosen system with their group and how the characteristics of a system relate to this chosen system.
     • Question: What is a system?
     • Answer: A system consists of many parts that usually influence each other to produce some result. Systems can be part of another system and may not work as well or at all if some part is broken or damaged.

2. Assess students’ Astro Journals to ensure that they have mastered the characteristics of systems.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
### Part 3: Thinking in Systems

<table>
<thead>
<tr>
<th>Thinking in Systems</th>
<th>The Solar System</th>
<th>Planetary Temperature as a System</th>
<th>Atmosphere &amp; Temperature</th>
<th>Atmospheric Mass</th>
<th>Disrupting the Systems</th>
</tr>
</thead>
</table>

#### AstroVenture: Astronomy Educator Guide EG-2002-10-001-ARC

**Name:**

**Date:**

4. What would happen if one part of your system was damaged or taken away?

5. The third characteristic of a system is:

6. How do the parts of your system relate to each other?

---

**AstroJournal Lesson 7: Thinking in Systems**

**System Chosen:**

1. The first characteristic of a system is:

2. Draw a concept map of the parts of your chosen system.

3. The second characteristic of a system is:
<table>
<thead>
<tr>
<th>Part 3</th>
<th>Thinking in Systems</th>
<th>The Solar System</th>
<th>Planetary Temperature as a System</th>
<th>Atmosphere &amp; Temperature</th>
<th>Atmospheric Mass</th>
<th>Disrupting the Systems</th>
</tr>
</thead>
</table>

**Name:**

**Date:**

**System Chosen:**

7. The fourth characteristic of a system is:

8. Draw a concept map of your system and how it is a part of another system.

9. Design a system that would perform an important or helpful function such as making your breakfast. Draw the system and explain how the characteristics of a system apply to your system.
Lesson 8: The Solar System

Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influences the system and the consequences of disrupting that system.

Main Lesson Concept: The Solar System is a system. One of the ways that the parts of the Solar System interact with each other is through gravity.

Scientific Question: How do the parts of the Solar System interact with each other?

- Mass is the measure of the quantity of matter.
- Gravity is a force of attraction that exists between objects. The greater the mass the greater its gravitational pull.
- The Sun’s gravitational pull holds Earth and other planets in their orbits, just as the planets’ gravitational pull keeps the planets’ moons in orbit around them.
- Everything on or near the Earth is pulled towards Earth’s center by gravitational force.
- Earth is one of several planets that orbits the Sun.
- A system consists of many parts that usually influence each other. (Lesson 7)
- An orbit is the path of an object around another object, caused by gravity.
- Two objects orbit around their center of mass.
**Suggested Timeline** (45-minute periods):
Day 1: Engage, Explore, and Explain Sections
Day 2: Extend/Apply Section
Day 3: Evaluate Section

**Materials and Equipment:**
- A class set of Astro Journal Lesson 8: The Solar System*
- A class set of Solar System Illustration Activity
- A tennis (or other) ball with a string securely attached
- An overhead transparency of Center of Mass
- Scientific Inquiry Evaluation Rubric
- Container of clay or play dough for each group
- A ruler for each student
- A scale for each group or string
- 2 Styrofoam™ balls (optional)
- 2 barbecue skewers (optional)
- Computer with browser and Internet connection
- Construction paper or butcher paper for each student.
- Chart paper

**Preparation:**
- Gather materials (e.g., string, tennis ball, clay or play dough, rulers, scales, string, Styrofoam™ balls, barbecue skewers, construction paper).
- Duplicate a class set of Astro Journals and Solar System Illustration Activity.
- Make overhead transparency of Center of Mass.
- Verify Links for Orrery Sites.
- Optional: Find more materials on orreries
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs, have students give an oral report or more limited writing assignment.

**Advanced Extensions**
Research star systems discovered outside of our own.
- How are they like our system?
- How are they different?
Part 3
Thinking in Systems  The Solar System  Planetary Temperature as a System  Atmosphere & Temperature  Atmospheric Mass  Disrupting the Systems

Engage  (approximately 5 minutes)

1. **Review systems.**
   - Question: When we’re thinking in terms of systems, what should we be thinking about?
   - Answer: Systems consist of many parts. The parts usually influence each other. A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected. Thinking about things as systems means looking for how every part relates to other parts. Any system is usually connected to other systems.

   - Question: Let’s think about our Solar System for a minute. What are the parts of the system?
   - Answer: The parts of the Solar System are planets, moons, the Sun, asteroids, etc.

2. **Go over the Scientific Question with students and state the purpose of the lesson.**
   - Scientific Question: How do the parts of the Solar System interact with each other?
   - Question: Why are we interested in how the parts of the Solar System interact with each other?
   - Answer: How the parts of the Solar System interact affects the Earth’s ability to support human life. Understanding this system will help us to understand how our planet and star system meet our survival needs.

3. **Record student responses on board/overheard/chart paper.**
   - Students record their Predictions in their Astro Journals.

Explore  (approximately 25 minutes)

1. **Introduce the demonstration.**
   - Say: There are many ways that the parts of the Solar System interact with each other. We’re going to explore one of them.

2. **Swing the ball attached to the string around.**
   - Question: Does this look like anything that occurs in the Solar System?
   - Answer: It looks like a planet travelling around the Sun or a moon travelling around a planet.

   - Question: Are there actually strings tying the planets to the Sun?
   - Answer: No, there are not any strings that tie the planets to the Sun.

   - Question: So what is keeping the planets moving around the Sun?
   - Answer: The Sun's gravitational pull is keeping the planets moving around the Sun.

   - Question: What is gravity?
   - Answer: Gravity is a force of attraction that exists between objects. The greater the mass of an object, the greater its gravitational pull.
• Say: When an object moves around another object because of gravity, that movement is called an orbit.

• Say: We’re going to take a closer look at how objects orbit around each other.

• Demonstration: Balance a ruler on your finger.
• Question: Why is this ruler balancing?
• Answer: There is equal mass on both sides of your finger.

**MISCONCEPTION:** Students tend to confuse mass and weight. The mass of an object refers to the quantity of matter in that object. Its weight is a measure of the gravitational attraction between it and the body that it’s on. Mass is an absolute quantity. It does not change when the object is on different bodies or even floating out in space. Weight will change. That is why the astronauts on the moon were able to make those long and high jumps. The discussion below will help to reveal this misconception.

• Question: On another planet would these balls have a different weight? How do you know?
• Answer: Yes. Astronauts on the moon weigh less, so they bounce when they walk.

• Question: On another planet, would these balls have a different mass? Explain.
• Answer: No. The balls would have the same amount of matter.

• Question: So what causes the change in weight?
• Answer: The gravitational pull causes the change in weight.

• Say: The reason these two balls balance is because they have the same amount of matter in them. Because they have the same amount of matter, they also have the same weight. On a different planet they would have a different weight. In space, they would have so little weight that you could barely detect it. No matter what the weight, they would always have the same amount of matter in them.

• Question: If I were to put a small ball of clay on one end of this ruler, what would I have to do to keep the ruler balanced?
• Answer: You would have to put a ball of equal mass on the other end.

• Question: What if the balls of clay did not have equal mass? Could I still balance the ruler?
• Answer: Yes. You’d have to move the balls to different parts of the ruler or your finger.

• Question: If we made the rule that the balls of clay had to stay at the ends of the ruler, where do you think your finger would have to be in order to balance two balls with these comparisons:
  • two balls of equal size
  • one ball that is twice the size of the other
  • one ball that is four times the size of the other
  • one ball that is eight times the size of the other
• Put students into groups.
• Give each group one container of clay or clay dough, and a ruler.
• Have students divide their clay dough into two equal parts and roll them into balls.
• If you have scales, have students weigh the balls to make sure they are the same size. If you don’t have scales, students could use a string and ruler to measure the circumference of each ball.

**Note to Teacher:** Warn students against compressing their clay too much if you can’t weigh the balls. They may look the same size, but have different densities, which could alter the results.
MISCONCEPTION: Students tend to believe that two objects of the same size have the same mass. To bring out this misconception, ask students what would happen if you had a marshmallow on one end and a clay ball of the same size on the other end and why. Help them observe that the clay is more massive than the marshmallow even though they are the same size.

- Have students balance the ruler with the balls on their finger, making sure to put the balls on either side of the ruler at the same distance from the ends.
- Have students record in their Astro Journals the number on the ruler at which the balls balance.
- Repeat this procedure for the other sizes, by having students divide one of the balls in half each time.
- Students fill in the Materials and Procedures sections of the Astro Journal.

Explain (approximately 20 minutes)

1. Have students share their findings with others in their group to see if they got similar results. Ask them to explain in their own words what is happening and record it in their Astro Journals.

   - Question: What would happen if we kept reducing the size of the smaller ball?
   - Answer: *Without the weight of the ruler interfering, eventually the balancing point would be under the larger ball.*

2. Show students the Center of Mass overhead transparency.

   Explain to students that orbits are caused by gravity and that the balancing points they have found are called the center of mass. The center of mass is the point in between the centers of both objects, where the two masses balance. Explain that when two objects orbit each other, they orbit around their center of mass.

   Note to Teacher: The equation for figuring out where the center of mass would be is: \( m_1 \times r_1 = m_2 \times r_2 \) where \( m_1 \) is the mass of the star, \( m_2 \) is the mass of the planet, \( r_1 \) is the distance from the star to the center of mass and \( r_2 \) is the distance from the planet to the center of mass.

   - Question: Where is the center of mass between Earth and the Sun, if the Sun's mass is 334,000 times that of Earth?
     - Answer: *The center of mass would be near the center of the Sun.*

   - Question: Does the Sun orbit?
     - Answer: *Yes. The Sun appears to be stationary, but actually does move around. This is because the Sun and the planets orbit around their center of mass. For our Solar System, the center of mass happens to be just outside the Sun.*

   - Say: The Sun is only 1,050 times the mass of Jupiter (considerably less than 334,000 times), so that this center of mass moves out enough to cause our Sun to move considerably more. This movement is called a wobble. When scientists detect a star that wobbles noticeably, they know that the star has a large planet orbiting it. You'll see this in the Astro-Venture Astronomy Mission Module.
3. **(Optional) Show students a model of this wobble.**
   - Take a large styrofoam ball and insert a skewer off center. Attach another, smaller styrofoam ball with another skewer at a right angle to the first skewer. Spin the larger ball on its skewer. Explain that it wobbles, because the center of mass is outside its own center. This is the same reason that the Sun wobbles, as Jupiter moves around it.

4. **Students fill in the “Finding the Balance“ Results and Conclusions section in their Astro Journals.**

---

**Extend/Apply (approximately 45 minutes)**

1. **Students model the Solar System.**
   - Question: Since it sometimes helps to understand something if we can visualize it, are there ways we can model our Solar System?
   - Answer: There are many ways to model our Solar System including planetaria, illustrations, etc.

   - Tell the students that in the early 1700s, an Irish nobleman, the Earl of Orrery, hired a watchmaker to build him a machine that would accurately show the movements of the planets.

   - Question: Why would someone hire a watchmaker to make such a machine?
   - Answer: Many of the earliest “clocks” marked the passage of time using the movement of astronomical bodies (the sun, the moon, and various planets). One of those clocks, the sundial became the model for the clock. It would not be that great of a stretch for a watchmaker to model the movement of astronomical bodies.

   Note to Teacher: An orrery is a limited model that shows the relative positions of the planets and an estimation of their movement. It will be contrasted later with a gravity simulator that can model the Solar System in a more realistic way - by simulating the gravitational effects of large bodies on each other.

   - Tell the students that they are going to be focusing on the distance of the planets from the sun. They will make a scale drawing of the planets in the Solar System from Mercury to Saturn.

   Note to Teacher: The distances will be to scale, but the planet sizes will not. The scale is also the reason we’re stopping at Saturn. The planets beyond Saturn would make the drawing too large.

   - Have students do the 'Solar System Illustration' activity, which is included with the Lesson 8 Astro Journal.

   - Introduce the 'Solar System Illustration' activity by reading over the directions with students. If students have not experienced working with scale, you may want to help them generate a chart that translates each distance into centimeters as follows:

     - Question: If Earth is 1 Astronomical Unit (AU) from the Sun, and in this scale, 1 AU is 2 centimeters (cm), how far away would we draw Earth?
     - Answer: Earth would be drawn 2 centimeters from the Sun.

     - Question: If Mercury is 0.4 AU from the Sun, how many centimeters would that be?
     - Answer: We multiply 2 centimeters times 0.4, which is 0.8 centimeters.
- Continue for each distance to generate the following chart.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Sun in AU's</th>
<th>Distance in cm (Scale: 1 AU = 2 cm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Venus</td>
<td>0.7</td>
<td>1.4</td>
</tr>
<tr>
<td>Earth</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Mars</td>
<td>1.5</td>
<td>3</td>
</tr>
<tr>
<td>Jupiter</td>
<td>5.2</td>
<td>10.4</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.6</td>
<td>19.2</td>
</tr>
</tbody>
</table>

Note to Teacher: Advanced students might also calculate and show center of mass using the formula: 
\[ m_1 \times r_1 = m_2 \times r_2 \]
where \( m_1 \) is the mass of the star, \( m_2 \) is the mass of the planet, \( r_1 \) is the distance from the star to the center of mass and \( r_2 \) is the distance from the planet to the center of mass.

**MISCONCEPTION:** Because of the difficulty of representing the Solar System to scale with both size and distance, students often do not have a true sense of relative sizes. For example, students often believe that Jupiter is close to the same size as the Sun. Ask students how big the Sun is compared to Jupiter (the Sun is about 10x the diameter of Jupiter). Ask students how big Jupiter is compared to Earth (Jupiter is about 10x the diameter of Earth). Discuss with students whether they will draw the planets and Sun to scale or not and why or why not. Discuss the importance of indicating that an image is not to scale.
• While the students are working on their illustrations, have them visit the following links about orreries.
Note to Teacher: Links are active as of August 2001. Check before using with students. Other resources about orreries can also be included. Have students focus on the idea that an orrery is a system. The mechanical orrery uses gears and cogs to model the mathematical relationships. The digital ones use calculations and images.

  - Mechanical Orreries
    - [http://www.geocities.com/CapeCanaveral/Hall/3551/ingle27.htm](http://www.geocities.com/CapeCanaveral/Hall/3551/ingle27.htm)
    - Carlos Croce is a clock-maker who has built an orrery. The written information is too complex for most students at the 5th to 8th grade level, but the pictures are beautiful and show some of the inner workings. He also shares some of the trials he went through in building the orrery.

  - Digital Orreries
      This is a basic orrery simulation written in Java, which shows the position of the planets on a given date then allows you to move forward or backward in time.
      This is an orrery with a twist. It allows you to view the planets from many points of view (including from other planets).

E v a l u a t e  (approximately 45 minutes)

1. Have students share their illustrations and explain to a partner or in a small group how the Solar System has the characteristics of systems.

2. Have students do the Results section for the lesson in their Astro Journals.
   - Go over rubric for essay (on the assignment sheet).
     Note to Teacher: You may want to be more specific with your students about the lengths of their essays. The students will be using one period for this. Plan essay length accordingly.

3. Discuss students' essays.
   - Question: Explain the Solar System as a system.
     - Answer: The Solar System is made up of parts, which include the Sun, planets, moons and asteroids. These parts are held together by gravity, which causes an attraction between all of the different parts and which keeps the parts of the system in their orbits. The system is pretty stable and balanced, as the parts of the system all orbit around their center of mass. Planets, moons and asteroids all stay in their orbits. However, if an object, such as a large planet, came into the Solar System from outside, it could disrupt the balance. It might run into another planet and change the orbits of the objects in the system.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
Astro Journal Lesson 8: The Solar System

1. Scientific Question:
   How do the parts of the solar system interact with each other?

2. Hypothesis/Prediction: How do you think the parts of the solar system interact with each other?

Name:
Date:

3. Results: On a separate sheet of paper, write a short essay that explains the solar system as a system.

Essays must include reference to the characteristics of systems:
- In systems that consist of many parts, the parts usually influence each other.
- A system may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or disconnected.
- Thinking about things as systems means looking for how every part relates to others.
- Any system is usually connected to other systems.

Also make sure to include orbits, center of mass and the role of gravity in the system. You may use your experiences with orreries to help your explanations.

Your essay will be evaluated using the following rubric.

4 • Essay clearly and accurately explains how the Solar System is a system.
   • Essay has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed explanation.

3 • Essay clearly and accurately explains how the Solar System is a system.
   • Essay has all required parts, makes specific references to examples, and uses good reasoning in explanations.

2 • Essay is not completely clear or accurate in explaining how the Solar System is a system.
   • Essay has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.

1 • Essay is not clear or accurate in explaining how the Solar System is a system.
   • Essay is not clear or accurate in explaining how the Solar System is a system. Essay is missing several parts, makes few specific references to examples, and uses little or no good reasoning.
Solar System Illustration Activity

Create an illustration that shows the Sun, the planets from Mercury to Saturn and their orbits around the Sun. The distances of the planets from the Sun should be drawn to scale. The size of the Sun and planets should reflect their relative sizes (Jupiter is larger than the Earth. The Sun is the largest of the bodies.), but a precise scale is not required. If planets and the Sun are not drawn to scale, be sure to indicate this. The illustration should include:

- a key
- a caption which explains orbits, center of mass, and the role of gravity in the Solar System

The chart below has the distance of the planets from the Sun using a scale called Astronomical Units or AU for short. One Astronomical Unit is the distance of the Earth from the Sun (149,637,000 kilometers or 93,000,000 miles). Please note that these distances are the average distance from the Sun. Depending on where the planet is in its orbit around the Sun, the actual distance may be greater or lesser.

<table>
<thead>
<tr>
<th>Planet</th>
<th>Distance from Sun in AU's</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.4</td>
</tr>
<tr>
<td>Venus</td>
<td>0.7</td>
</tr>
<tr>
<td>Earth</td>
<td>1</td>
</tr>
<tr>
<td>Mars</td>
<td>1.5</td>
</tr>
<tr>
<td>Jupiter</td>
<td>5.2</td>
</tr>
<tr>
<td>Saturn</td>
<td>9.6</td>
</tr>
</tbody>
</table>

The most direct way to make your drawing to scale is to have 1 AU be equivalent to 2 centimeters (cm) or 1 inch. Using this scale, Earth would orbit 2 cm away from the Sun. **You must include your scale in your key and indicate which elements are to scale and which are not.**

Uranus, Neptune and Pluto have been left off because their distance would make the illustration too large.
Your illustration will be assessed using the following rubric.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The planets and orbits are accurately, creatively and elegantly portrayed in the illustration. The caption clearly and accurately portrays orbits, center of mass, and the role of gravity in the Solar System. Elements on the poster are spaced appropriately and design elements (color, lines, shapes, and content illustrations) make the poster exceptionally clear and easy to understand.</td>
</tr>
<tr>
<td>3</td>
<td>The planets and orbits are clearly and accurately portrayed in the illustration. The caption clearly and accurately portrays orbits, center of mass, and the role of gravity in the Solar System. Elements on the illustration are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make the illustration easy to read and understand.</td>
</tr>
<tr>
<td>2</td>
<td>The planets and orbits are not completely clear or accurately portrayed in the illustration. The caption does not completely clearly or accurately orbits, center of mass, and the role of gravity in the Solar System. Elements on the illustration could be better spaced and design elements (color, lines, shapes, and content illustrations) make the illustration a little difficult to read.</td>
</tr>
<tr>
<td>1</td>
<td>The planets and orbits are unclear or inaccurate in the illustration. The caption does not clearly and accurately explain orbits, center of mass, and the role of gravity in the Solar System. Elements on the illustration are either squashed together or large spaces are empty, and design elements (color, lines, shapes, and content illustrations) make the illustration difficult to read.</td>
</tr>
</tbody>
</table>

Illustration Self-Evaluation

Evaluate your work using the rubric. Give your work a score and then explain why you think the work deserves that score. Make references to specific parts of your illustration when explaining your score.

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________

__________________________________________________________________________________________________________________________
Center of Mass

The balancing point between two masses.
Lesson 9: Planetary Temperature as a System

Students explore the planetary temperature system. They further explore how each part influences the system and the consequences of disrupting that system.

**Main Lesson Concept:** The type of star and the distance of a planet from the star affects two major parts of the system that controls the surface temperature of a planet (planetary temperature system). The hotter a star is, the further the planet needs to orbit in order to maintain liquid water on its surface.

**Scientific Question:** What are two important parts of the planetary temperature system? How do these parts work together to determine a planet’s surface temperature?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
</table>
| Students will explain how star type and the distance of a planet from its star work together to affect the planetary temperature system. | Meets: 2061: 11A 6-8 #2
| Students will categorize stars on a Hertzsprung-Russell (HR) Diagram. They will also model the relationship of star type and orbital distance and will draw conclusions about the stars most suitable for supporting human life. | NSES: UCP1 K-12
| | Addresses:
| | NSES: A 5-8 #1
| | NCTM: 2, 5, 9 |

**Assessment**

Write-up in Astro Journal, Diagram of a star and its Habitable Zone.

**Abstract of Lesson**

Students categorize stars on a HR diagram and explore the characteristics of the types of stars most suitable for supporting human life. They then explore the interaction of star type and orbital distance in determining the temperature of a planet by modeling this interaction.

**Prerequisite Concepts**

- The Sun’s gravitational pull holds Earth and other planets in their orbits, just as the planets’ gravitational pull keeps their moons in orbit around them.
- A system consists of many parts that usually influence each other. (Lesson 7)
- An orbit is the path of an object as it moves around another object because of gravity. (Lesson 8)
- An Astronomical Unit (AU) is the average distance between the Sun and Earth and is equivalent to 149,598,770 kilometers or 93,000,000 miles.
- Temperature is the measure of the average kinetic energy (or movement) of the molecules of a system. (Lesson 6)
- Luminosity is the brightness of a star.

**Major Concepts**

- Scientists categorize stars by their temperature and brightness or luminosity.
- Stars in the middle of the main sequence on the HR Diagram (yellow stars) are ideal for human life, as they burn at a moderate temperature that remains relatively stable over time.
- The Habitable Zone is the area around a star in which a planet could maintain liquid water on or near its surface. This zone changes in distance from the star and in the width of the zone depending on the temperature of the star.
- The temperature of a star and the orbital distance of a planet work together to affect the planet’s surface temperature.
| Part 3 | Thinking in Systems | The Solar System | Planetary Temperature as a System | Atmosphere & Temperature | Atmospheric Mass | Disrupting the Systems |

**Suggested Timeline** (45-minute periods):

Day 1: Engage and Explore Sections  
Day 2: Explain Section  
Day 3: Extend/Apply and Evaluate Sections

**Materials and Equipment:**

- A class set of Astro Journals Lesson 9: Planetary Temperature as a System*  
- Grouping Star Cards for each group  
- One copy of Are You My Type (cut so that each student has one)  
- Overhead transparency of Blank HR Diagram  
- Overhead transparency of Completed HR Diagram  
- Transparency pens of different colors (blue, red, orange, yellow)  
- A class set of Star Type Reading  
- A class set of Habitable Zone Reading  
- Chart paper/board  
- Overhead projector  
- Class set of scissors

**Preparation:**

- Prepare overhead for lesson.  
- Gather materials (i.e., transparency pens, scissors).  
- Create overhead transparencies of Blank HR Diagram and Completed HR Diagram.  
- Copy a class set of Astro Journals: Lesson 9, Star Type Reading: Lesson 7 and Habitable Zone Reading: Lesson 5.  
- Copy a set of Star Cards for groups.  
- Copy and cut a class set of Are You My Type.  
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**  
For students who may have special needs, provide extra support for reading assignment (e.g. partner, read aloud, etc.).

**Advanced Extensions**  
Have students research and report on one of the following questions:  
- Is a star the only source of heat for a planet?  
- Is a star always the same type throughout its life?  
- Is the Habitable Zone the same for microbes?  
  Why or why not?  
- What is the Habitable Zone of a galaxy?  

(Some advanced students may enjoy reading the book *Rare Earth* by Peter Ward that goes into many of these topics in much more detail than Astro-Venture.)
Engage (approximately 15 minutes)

1. Review the Solar System as a system.
   - Question: How is the Solar System a system?
   - Answer: The Solar System has many parts (the Sun and planets primarily) which are held together by gravity.

   - Question: One of the characteristics of a system is that it is usually connected to other systems or contains smaller systems within it. If we look at the Earth by itself, what systems does the Earth have?
   - Answer: The Earth has many systems such as our weather system, ecosystems, the rock cycle, water cycle, carbon cycle, nitrogen cycle, etc.
   - Say: The system on which we will be focusing is the system that determines the surface temperature on a planet.

2. Present the Scientific Question(s):
   - What are two important parts of the system that controls the surface temperature of a planet (planetary temperature system)? How do these parts work together to determine a planet's surface temperature?

3. Record student responses on board/overheard/chart paper.
   - Students record their predictions in the Prediction section of their Astro Journals.

4. Introduce the planetary temperature system.
   - Question: We’re going to be looking at the system that controls the surface temperature of a planet or the “planetary temperature system”. What determines the surface temperature of a planet?
   - Answer: The most important part of the planetary temperature system is to have a source of heat, which is usually a star. (Other parts of the system that students may or may not bring up are the distance of a planet from its star and the amount and composition of its atmosphere.)

   Note to Teacher: Another source of heat could be the internal heat of a planet. Microbes on Earth obtain heat and energy from the heat vents on the ocean floor. This heat comes from inside the Earth. In fact, Jupiter and Saturn radiate more heat than they receive from the Sun. The source of this heat is internal and originates from the formation of the planet. Similarly heat on some satellites such as Jupiter’s moon, Europa, is caused by tidal friction, as Europa expands and contracts when the gravitational pull of another satellite increases and decreases as it orbits close to and then far away from Europa. The gravitational pull on Europa fluctuates so much that it causes the planet to flex, generating heat in the process.

   - Question: Let’s pretend that our heat source is a campfire and that we are planets around the campfire. What other factor is going to determine how hot or cold we are?
   - Answer: The other factor, which will determine how hot or cold we become is our distance from the campfire.

   - Question: What happens when we go closer to the campfire?
   - Answer: When we move closer to the campfire we feel warmer.

   - Question: What happens when we go further away from the campfire?
   - Answer: When we move further away from the campfire, we feel colder.
5. **Introduce the Purpose of the lesson.**

   - **Question:** Why do we care about the temperature of a planet?
   - **Answer:** Planetary temperature is important in order for humans to survive. Humans need a stable temperature that allows water to be liquid at all times.

   - **Say:** Today we will be looking at two important parts of the planetary temperature system and how they work together. We will first focus on stars, the different types of stars there are and decide which would be the best kind to have in our system. We will then look at how orbital distance works with star type to determine the temperature of a planet and which star type and distance are ideal for human habitability.

---

**Explore** *(approximately 30 minutes)*

1. **Introduce star type.**

   - **Question:** In the Astronomy Training Module, what kind of star was needed to support human life?
   - **Answer:** A yellow star was needed to support human life.
   - **Tell students that they’re going to be exploring what that concept means in a little more depth.**

   - **MISCONCEPTION:** People sometimes confuse stars and planets or do not make the connection that the Sun is actually a star.

     - **Question:** How are stars different from planets?
     - **Answer:** A star is a large, hot ball of gases, which gives off its own light. A planet is a large body that does not give off its own light and is orbiting a star. A planet is generally much smaller than a star and can be made of solid, liquid and/or gas.

2. **Discuss star categorizing.**

   - **Say:** Often times we put things into categories based on certain characteristics. For example, we can categorize automobiles by type (car, truck, SUV), by color, by size (sub-compact, compact, mid-size, luxury) or any number of other characteristics.

   - **Question:** What characteristics do you think scientists would use to categorize stars?
   - **Record students’ ideas on the board.**

3. **Engage students in star categorizing activity.**

   - **Note to Teacher:** If students are not familiar with the term “luminosity”, discuss this concept before beginning the activity. Luminosity is the brightness of a star.

   - **Put students into groups and give each group a copy of Grouping Stars Cards.**
   - **Have students cut out the cards and put them in categories.** As an example, use distance from Earth to sort the stars. Sample categories might be: less than 10 light years, 10 to 100 light years and more than 100 light years. Have students list the star names that fit in each category.
   - **Have groups come up with as many different categories as they can and then have them list the categories and the stars that fit in each category.**
   - **Have students share their categories.** List the different categories on the board/chart/overhead.

   - **Possible categories might include Main Sequence stars and giants; temperature ranges of 0-3500 Kelvins, 3501-6,000 Kelvins, 6,001-10,000 Kelvins and over 10,000 Kelvins; star diameter ranges of 1 to 3 Suns, 4 to 12 Suns and more than 100 Suns.**
POSSIBLE CONFUSION We’re focusing on both systems and categories in this lesson. This may initially cause confusion, but in exploring their similarities and differences, students can gain a better understanding of both systems and categories.

- Question: How are categories and systems different?
  - Answer: Categories are groupings based on characteristics. Systems are groupings based on the interactions of the parts of the system.

- Question: How are systems and categories similar?
  - Answer: Systems and categories are similar in that they are both ways of grouping things.

4. Discuss categories.
   - Have students share their categories and list them on the board. Discuss which categories students think are best and why.
   - Tell students that scientists classify stars by their temperature and brightness or luminosity. By graphing stars according to luminosity over temperature, they have observed groups of stars. Students will observe this in the following activity.

**Explain** (approximately 30 minutes)

1. Engage students in the HR Diagram activity.
   - Hand out an Are You My Type? Card to each student.

   - Have students group themselves with others in the class that have similar temperature and luminosity.

   - Project the Blank HR diagram on an overhead projector.

   - Have students come up and using transparency pens, draw a star where it would go on the HR diagram. Encourage students to use the color pen that fits the section of the HR diagram where the star is located. If their star is a giant, encourage them to draw a larger star. White stars can be drawn as unfilled circles. Have them label the star with its name.

   **Note to Teacher:** Alternative methods of having students plot their stars are to:
   - Recreate a large version of the HR Diagram on chart paper. Post the chart on a bulletin board, and have students use pushpins or stickers for stars.
   - Draw the HR Diagram with sidewalk chalk outside, and have students place themselves on the diagram.
2. Discuss with students the patterns they observe on the HR Diagram.

- Question: What groups of stars do you observe on the diagram?
  - Answer:
    - There is a band of stars that stretches from the top left corner to the bottom right.
    - There are two clusters of stars in the top right.
    - There is another cluster of stars in the bottom left.

- Post the transparency of the Completed HR Diagram.
- Say: We call the band of stars that stretches at a diagonal, Main Sequence stars. The two clusters in the top right are called giants and supergiants. The bottom left cluster of stars is called the white dwarfs. We'll learn more about these different types of stars in our reading.
- Post the Blank HR Diagram again.

- Question: Is there a relationship between temperature and luminosity? (In particular, look at the Main Sequence stars) If so, how do you know?
  - Answer: Yes, there is a relationship between temperature and luminosity. The stars show a definite pattern instead of being scattered all over the diagram.

- Question: What is the relationship between temperature and luminosity?
  - Answer: The hotter a star is, the greater its luminosity.

- Question: Is there a relationship between the number of stars and their temperature and luminosity? If so, what is it?
  - Answer: There are more stars that are cool and dim than there are stars that are hot and bright.
3. Read with students the Star Type Reading.
   - Discuss the different kinds of stars and how scientists categorize them.
   - Have students answer the comprehension questions.

4. Discuss conclusions about star type and bridge to Habitable Zone Activity.
   - Question: What kind of star is ideal for human life? Why?
     - Answer: A moderate, yellow star in the middle of the Main Sequence is ideal for human life, because it has a moderate temperature that remains pretty stable.
   - Question: Would it be possible to have a different star type and just move my planet to a different distance?
     - Answer: That scenario may be possible in some cases.

Extend/Apply (approximately 35 minutes)

- Say: We will look at this possibility in the next activity.

1. Introduce the concept of the Habitable Zone Activity.
   - Question: What temperature do we want to have on our planet’s surface at all times?
     - Answer: We want a temperature that allows water to be liquid at all time.
   - Question: Why is this important?
     - Answer: Humans need water to survive.
   - Say: We call the distance at which water is a liquid at all times the Habitable Zone. The Habitable Zone for our Sun (a star of mass 1) and an earth-size planet is 0.9 to 1.5 AU.

2. Engage students in physically modeling the planetary temperature system.
   - Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (so their arm can go up and down). Place yourself in the center of the circle. Tell students that they are planets orbiting you, their star.
   - Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet that allows water to be a liquid. As I make some changes to the system, make the appropriate change with your arm.
   - Say: O.K. You’re planet is starting to move closer to its star. What is happening to its temperature?
     - Answer: Arms go up.
   - Say: Now it’s moving farther away. What’s happening?
     - Answer: Arms go down.
• Say: What would happen if I were a blue star?
  • Answer: Arms go up.

• Question: What would you, as planets, need to do to keep the right temperature for liquid water?
  • Answer: We would need to move further away from the star. (Have students do this and move their arms back to the middle position).

• Say: As it turns out, blue stars are very unstable, so their temperature changes a lot. I’m going to stick out my arm to show you what my temperature is doing, and you show me what you need to do to keep your temperature stable. (Move your arm up and down. Students should move forward and back.)

• Question: Do planets move toward and away from their star as they orbit in the way we just modelled?
  • Answer: No. Planets move in elliptical orbits, so at times may be closer or further from their star, but they don’t move in zig-zags.

• Question: So what can we say about blue stars?
  • Answer: Blue stars are not ideal for human habitability, because their temperature changes too much.

• Say: Blue stars also burn out much quicker than other stars which is not ideal for human habitability.
• Question: Now, what is going to occur if I am a red star?
  • Answer: Arms go down.

• Question: What would you need to do to maintain the right temperature for liquid water?
  • Answer: To maintain the right temperature for liquid water, we need to move closer to the star. (Have students move very close to you and move arms to middle position.)

• Question: Are there any problems with being this close to a star?
  • Answer: Yes. A star puts out a lot of radiation, which would kill humans.

• Question: So would a red star be ideal for human habitability.
  • Answer: No.

• Question: What would happen if you planets were in elliptical orbits?
  • Answer: Arms move up and down.

• Question: Why does your temperature change?
  • Answer: The planets are moving closer and further from the star. When they are far from the star, the temperature decreases. When they are closer to the star, the temperature increases.

• Question: So what can we say is important about a planet’s orbit in order to be habitable?
  • Answer: The planet needs to be in a near circular orbit to be in the Habitable Zone at all times.

• Question: Do star systems actually change like this?
  • Answer: No.

• Question: Then why are we doing this?
  • Answer: To model the planetary temperature system.
3. **Read with students the Habitable Zone Reading.**
   - Discuss the meaning of Habitable Zone and why it's important to life.
   - Have students answer the comprehension questions.

4. **Discuss conclusions from the Habitable Zone Reading and Activity.**
   - **Question:** Is the Habitable Zone the same for all stars? Why not?
   - **Answer:** No, the Habitable Zone is not the same for all stars, because stars all have different temperatures.
   - **Question:** Does a star's Habitable Zone stay the same all the time? Why not?
   - **Answer:** No. Stars' temperature changes over time.
   - **Question:** Are yellow stars the only stars that can support human life?
   - **Answer:** We don't know for sure; however, moderate stars like our Sun seem to be ideal to support human life. We do believe that it is very unlikely that blue stars and red stars could support humans.

5. **Have students complete the Results and Conclusions sections of their Astro Journal.**

---

**Evaluate** (approximately 10 minutes)

1. **Discuss students’ Results and Conclusions.**
   - **Question:** How do star type and orbital distance work together to determine a planet’s surface temperature?
   - **Answer:** The hotter a star is, the further the planet needs to be in order to maintain a moderate temperature.

   - **Question:** What star type is ideal for human habitability? Why?
   - **Answer:** The star type that is ideal for human habitability are moderate, yellow stars, because they have a stable, moderate temperature.

   - **Question:** What is the ideal orbit for a planet to support human life? Why?
   - **Answer:** The ideal orbit for a planet to support human life is a circular orbit at a distance that falls in the Habitable Zone so that the planet maintains a temperature where water is a liquid at all times. This is important, because humans need water to survive.

---

**Note to Teacher:** After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
## Astro Journal Lesson 9: Planetary Temperature as a System

### 1. Scientific Question:
What are two important parts of the planetary temperature system? How do these parts work together to determine a planet’s surface temperature?

### 2. Hypothesis/Prediction:
What do you think are two important parts of the planetary temperature system? How do you think these two parts work together to determine a planet’s surface temperature?

### 3. Results:
What are two important parts of the planetary temperature system? How do these parts work together to determine a planet’s surface temperature?

### 4. Conclusions:
Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the molecules change your original ideas?

What type of star is ideal for humans? Why?

What is the ideal orbit for a planet to support humans? Why?
Grouping Stars Cards

**Star Name:** Capella  
**Distance from Earth** (in light years): 44  
**Luminosity class:** giant  
**Temperature:** 5,100 Kelvins  
**Diameter in suns:** 11  
**Luminosity in suns:** 72

**Star Name:** Betelgeuse  
**Distance from Earth** (in light years): 325  
**Luminosity class:** supergiant  
**Temperature:** 3,400 Kelvins  
**Diameter in suns:** 265  
**Luminosity in suns:** 5,000

**Star Name:** Hoedus 11  
**Distance from Earth** (in light years): 310  
**Luminosity class:** main-sequence  
**Temperature:** 21,000 Kelvins  
**Diameter in suns:** 3  
**Luminosity in suns:** 377

**Star Name:** Almaaz  
**Distance from Earth** (in light years): 6,500  
**Luminosity class:** supergiant  
**Temperature:** 7,200 Kelvins  
**Diameter in suns:** 365  
**Luminosity in suns:** 200,000

**Star Name:** Sirius  
**Distance from Earth** (in light years): 9  
**Luminosity class:** main-sequence  
**Temperature:** 9,700 Kelvins  
**Diameter in suns:** 2  
**Luminosity in suns:** 21

**Star Name:** Gomeisa  
**Distance from Earth** (in light years): 140  
**Luminosity class:** main-sequence  
**Temperature:** 13,000 Kelvins  
**Diameter in suns:** 2  
**Luminosity in suns:** 95

**Star Name:** Ross 154  
**Distance from Earth** (in light years): 9.3  
**Luminosity class:** main-sequence  
**Temperature:** 2,800 Kelvins  
**Diameter in suns:** 0.63  
**Luminosity in suns:** 0.02

**Star Name:** Ross 248  
**Distance from Earth** (in light years): 10.3  
**Luminosity class:** main-sequence  
**Temperature:** 2850 Kelvins  
**Diameter in suns:** 0.32  
**Luminosity in suns:** 14.7

**Star Name:** Pollux  
**Distance from Earth** (in light years): 35  
**Luminosity class:** giant  
**Temperature:** 4,900 Kelvins  
**Diameter in suns:** 9  
**Luminosity in suns:** 32

**Star Name:** Alzirr  
**Distance from Earth** (in light years): 59  
**Luminosity class:** giant  
**Temperature:** 6,600 Kelvins  
**Diameter in suns:** 2  
**Luminosity in suns:** 11
### Are You My Type of Star? (1 of 3)

<table>
<thead>
<tr>
<th><strong>Star Name</strong></th>
<th><strong>Luminosity class</strong></th>
<th><strong>Temperature</strong></th>
<th><strong>Luminosity in suns</strong></th>
<th><strong>Absolute Magnitude</strong></th>
<th><strong>Star Type</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Sol</td>
<td>main-sequence</td>
<td>5,800 Kelvins</td>
<td>1</td>
<td>+4.74</td>
<td></td>
</tr>
<tr>
<td>Propus</td>
<td>giant</td>
<td>3,100 Kelvins</td>
<td>125</td>
<td>-0.5</td>
<td></td>
</tr>
<tr>
<td>Ross 154</td>
<td>main-sequence</td>
<td>2,800 Kelvins</td>
<td>0.02</td>
<td>+13.3</td>
<td></td>
</tr>
<tr>
<td>Ross 248</td>
<td>main-sequence</td>
<td>2850 Kelvins</td>
<td>0.006</td>
<td>+14.7</td>
<td></td>
</tr>
<tr>
<td>Hoedus II</td>
<td>main-sequence</td>
<td>21,000 Kelvins</td>
<td>377</td>
<td>-1.7</td>
<td></td>
</tr>
<tr>
<td>V. Maanen’s star</td>
<td>white dwarf</td>
<td>12,000 Kelvins</td>
<td>0.002</td>
<td>+12.4</td>
<td></td>
</tr>
<tr>
<td>Aludra</td>
<td>supergiant</td>
<td>14,500 Kelvins</td>
<td>50,000</td>
<td>-7.0</td>
<td></td>
</tr>
<tr>
<td>Rex Donaldix</td>
<td>main-sequence</td>
<td>5770 Kelvins</td>
<td>0.79</td>
<td>+5.1</td>
<td></td>
</tr>
<tr>
<td>Samuelsonian</td>
<td>main-sequence</td>
<td>3,850 Kelvins</td>
<td>0.077</td>
<td>+8.8</td>
<td></td>
</tr>
<tr>
<td>Hassaleh</td>
<td>giant</td>
<td>4,200 Kelvins</td>
<td>655</td>
<td>-2.3</td>
<td></td>
</tr>
</tbody>
</table>
### Are You My Type of Star? (2 of 3)

<table>
<thead>
<tr>
<th>Star Name</th>
<th>Luminosity class</th>
<th>Temperature</th>
<th>Luminosity in suns</th>
<th>Absolute Magnitude</th>
<th>Star Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>αCen A</td>
<td>main-sequence</td>
<td>5830 Kelvins</td>
<td>1.7</td>
<td>+4.4</td>
<td>Star</td>
</tr>
<tr>
<td>Luyten</td>
<td>white dwarf</td>
<td>16,000 Kelvins</td>
<td>0.002</td>
<td>+12.5</td>
<td></td>
</tr>
<tr>
<td>Amberan</td>
<td>main-sequence</td>
<td>5,860 Kelvins</td>
<td>1.1</td>
<td>+4.7</td>
<td></td>
</tr>
<tr>
<td>Mattrix</td>
<td>main-sequence</td>
<td>3,580 Kelvins</td>
<td>0.045</td>
<td>+9.9</td>
<td></td>
</tr>
<tr>
<td>UV Cet B</td>
<td>main-sequence</td>
<td>2,850 Kelvins</td>
<td>0.002</td>
<td>+15.8</td>
<td>Star</td>
</tr>
<tr>
<td>Rigel</td>
<td>supergiant</td>
<td>13,000 Kelvins</td>
<td>55,000</td>
<td>-7.1</td>
<td></td>
</tr>
<tr>
<td>Grb 34A</td>
<td>main-sequence</td>
<td>3680 Kelvins</td>
<td>0.02</td>
<td>+10.3</td>
<td>Star</td>
</tr>
<tr>
<td>Nihal</td>
<td>giant</td>
<td>5,600 Kelvins</td>
<td>545</td>
<td>-2.1</td>
<td></td>
</tr>
<tr>
<td>Furud</td>
<td>main-sequence</td>
<td>18,000 Kelvins</td>
<td>377</td>
<td>-1.7</td>
<td>Star</td>
</tr>
<tr>
<td>Pollux</td>
<td>giant</td>
<td>4,900 Kelvins</td>
<td>32</td>
<td>+0.98</td>
<td></td>
</tr>
</tbody>
</table>
### Are You My Type of Star? (3 of 3)

<table>
<thead>
<tr>
<th>Star Name</th>
<th>Luminosity class</th>
<th>Temperature</th>
<th>Luminosity in suns</th>
<th>Absolute Magnitude</th>
<th>Star Type</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Christinaurus</strong></td>
<td>main-sequence</td>
<td>5,900 K</td>
<td>0.86</td>
<td>+5.1</td>
<td></td>
</tr>
<tr>
<td><strong>Dosereb</strong></td>
<td>main-sequence</td>
<td>5,770 K</td>
<td>0.79</td>
<td>+5.1</td>
<td></td>
</tr>
<tr>
<td><strong>Σ2398 A</strong></td>
<td>main-sequence</td>
<td>3,180 K</td>
<td>0.03</td>
<td>+11.1</td>
<td></td>
</tr>
<tr>
<td><strong>Lac 9352</strong></td>
<td>main-sequence</td>
<td>3,530 K</td>
<td>0.05</td>
<td>+9.6</td>
<td></td>
</tr>
<tr>
<td><strong>Castor</strong></td>
<td>main-sequence</td>
<td>9,300 K</td>
<td>28</td>
<td>+1.14</td>
<td></td>
</tr>
<tr>
<td><strong>Geofferan</strong></td>
<td>main-sequence</td>
<td>5,570 K</td>
<td>0.66</td>
<td>+5.5</td>
<td></td>
</tr>
<tr>
<td><strong>Sundownus</strong></td>
<td>main-sequence</td>
<td>3,370 K</td>
<td>0.019</td>
<td>+11.3</td>
<td></td>
</tr>
<tr>
<td><strong>Alisan</strong></td>
<td>main-sequence</td>
<td>3,050 K</td>
<td>0.005</td>
<td>+13.5</td>
<td></td>
</tr>
<tr>
<td><strong>Ain</strong></td>
<td>giant</td>
<td>5,000 K</td>
<td>65</td>
<td>+0.2</td>
<td></td>
</tr>
<tr>
<td><strong>Aldebaran</strong></td>
<td>giant</td>
<td>4,000 K</td>
<td>137</td>
<td>-0.6</td>
<td></td>
</tr>
</tbody>
</table>

---

Star Type:

* Indicates a star with a high luminosity.
Star Type Reading

The manner in which a star’s life ends depends upon its mass. Stars of low mass expand into red giants. Red giants eventually shed their outer layers of gas to leave behind the very hot core of the star to become white dwarfs. Those stars with a larger mass expand into supergiants that use up energy so fast that they become unstable and explode into supernovas. A supernova will either become a very dense star called a neutron star or will collapse into a black hole.

How do scientists decide a star’s type?
A star’s type is determined by its temperature (measured in Kelvin), mass and luminosity. For main-sequence stars, the Hertzsprung-Russell (H-R) diagram shows that there is a relationship between these features. The larger a main-sequence star is, the hotter and more luminous it is. A star’s color is related to its surface temperature. The coolest, smallest, dimmest stars are red dwarfs. Hotter, medium-sized stars are yellow stars, and the hottest, largest, most luminous main-sequence stars are blue stars.

What are the different types of stars?
Stars change over time. Different stages in a star’s life represent the different star types. Stars are born from clouds of gas and dust called nebulae and start out as protostars. These young stars eventually become main-sequence stars that burn hydrogen and range from hot, bright, massive blue stars to cooler, dimmer, less massive red dwarfs. Stars spend most of their lives as main-sequence stars.

When a main-sequence star runs out of hydrogen, it can begin using other fuels. Its temperature and luminosity change. This marks the beginning of the end of its life. The end of a star’s life is short compared to the amount of time it spends as a main-sequence star.

Other star types include giants, white dwarfs and red dwarfs. Giants are very large stars and include red giants and supergiants. White dwarfs and red dwarfs are very small, dim, but hot stars.
What makes the Sun so great?

The Sun is an ideal star for life compared to other main-sequence stars, because it is stable and so keeps Earth’s temperature constant. The Sun also burns for a long time.

How will the Sun’s life end?
Since scientists have evidence that the Sun will become a red giant in 5 billion years, this is the future we can imagine for our planet.

Questions
(Answer on a separate sheet of paper)

1. What are the stages in a low-mass star’s life?
2. What are the stages in a high-mass star’s life?
3. What determines a star’s type?
4. What makes the Sun an ideal star for life?
5. Is the Sun a low-mass or high-mass star?
6. Looking at the H-R diagram, what are the:
   • hottest, dimmest stars?
   • coolest, dimmest stars?
   • brightest, hottest stars?
   • brightest, coolest stars?

Hertzsprung-Russell Diagram
Habitable Zone Reading

What is the Habitable Zone?
Life as we know it needs liquid water to survive. The Habitable Zone is the distance from a star where liquid water can exist on a planet’s surface. If a planet is too far from its star, water freezes. If a planet is too close to its star, water evaporates. A planet must stay in the Habitable-Zone throughout its orbit in order for water to remain a liquid.

Where is the Habitable Zone?
The distance at which a planet can have water is determined by how much energy is given off by the star. This distance is measured in astronomical units or AU. An astronomical unit is the average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles. For cooler red dwarfs, the Habitable Zone is so close to the star that solar flares and radiation from the star would destroy life. For very hot blue stars, the Habitable Zone is further away. These stars tend to burn at such high temperatures that they have very short lives, lasting only a few million years. (It took 700 million years for life to become established on Earth). Our Sun’s Habitable Zone for larger life forms including humans is between 0.9 AU to 1.5 AU.

Is the Habitable Zone always in the same place?
The Habitable Zone can move as a star changes. As a star grows older, it grows hotter causing the zone to move further away from the star. At one time, Earth was on the outer edge of the Sun’s Habitable Zone, but now the zone has moved further away, so Venus is no longer in the Habitable Zone. Since stars change, it is important to have a star has a temperature that stays about the same for a long time. It’s also important that the orbit of an Earth-size planet be in the area of the zone that remains in the zone as the zone changes.

If I’m in the Zone, is Survival Guaranteed?
Even if a planet is in the Habitable Zone throughout its entire orbit, human survival is not guaranteed. The planet may not even have water on it to begin with, or the water it has may not be liquid. Mars, for example, has such a low surface pressure that its water cannot be a liquid on the surface. Water goes from a solid to a gas without ever being liquid.

Also, the planet may not have the right kind of atmosphere and may not be the right size to hold on to the atmosphere that humans need. Without the right kind of atmosphere to trap heat and maintain a stable temperature, surface water would not be found on a planet. Furthermore, the planet may not host plant and animal life that humans can eat. Finally, there may be other dangers, such as large planets, solar flares or radiation, from which humans need protection.
Is the Habitable Zone the same for all life?

The Habitable-Zone for microbes is much larger than the Habitable-Zone for humans, because microbes can survive under conditions that humans cannot. A microbe is an animal or plant so small it can be seen only with a microscope. A bacterium is an example of a microbe. There are microbes that can survive in the frozen ice of Antarctica and in the extremely hot, thermal vents on the ocean floor. That’s why scientists are looking for life on Mars and one of Jupiter's moons, Europa.

Questions
(Answer on a separate sheet of paper)

1. What is the definition of Habitable Zone?

2. Are all stars' Habitable Zones at the same distance? Why or why not?

3. What would happen if a planet weren’t in the Habitable Zone?

4. Would a microbe’s Habitable Zone be closer or further from a star than a human’s Habitable Zone? Explain your answer.
Lesson 10: Atmosphere & Temperature

Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influences the system and the consequences of disrupting that system.

**Main Lesson Concept:** The atmosphere of a planet affects the planetary temperature system, which determines the temperature of that planet.

**Scientific Question:** How does the atmosphere of a planet affect the planetary temperature system?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will explain and illustrate that atmosphere can raise the temperature of a planet.</td>
<td><strong>Meets:</strong> 2061: 11A 6-8 #2</td>
</tr>
<tr>
<td>Students put together a concept map that shows the parts of the planetary temperature system.</td>
<td>NSES: UCP K-12 #1</td>
</tr>
<tr>
<td>Students will explain why atmosphere is important to habitability and how star type, distance and atmosphere all work together to determine a planet’s temperature system.</td>
<td>NSES: A 5-8 #1</td>
</tr>
<tr>
<td></td>
<td><strong>Addresses:</strong> NSES: A 5-8 #1</td>
</tr>
<tr>
<td></td>
<td>NCTM: 4, 5, 9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Write-up in Astro Journal: Concept Map of Temperature System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Abstract of Lesson</td>
<td>Students use the inquiry process to explore the effect of atmosphere on the temperature of a planet. They create a model of the system to test. They then create a concept map of the planetary temperature system.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisite Concepts</th>
<th>Major Concepts</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Temperature measures the motion of molecules in a substance. (Lesson 6)</td>
<td>• Atmosphere traps heat, which increases and sustains the temperature of the planet.</td>
</tr>
<tr>
<td>• Atmosphere is the blanket of gases that surrounds some planets and moons.</td>
<td>• A planet’s temperature is determined by a combination of factors including the temperature of the star, the distance of the planet from the star and the amount and composition of the planet’s atmosphere.</td>
</tr>
</tbody>
</table>
**Suggested Timeline** (45-minute periods):
Day 1: Engage and Explore Day 1 Sections
Day 2: Explore Day 2, Explain, Extend/Apply and Evaluate Sections

**Materials and Equipment:**
- A class set of Astro Journals Lesson 10: Atmosphere and Temperature*
- A class set of Planetary Comparison Charts
- Thermometers
- Plastic Wrap
- Mountable lights (to function as a heat source)
- Chart paper

**Preparation:**
- Gather materials (e.g., thermometers, saran wrap, mountable lights)
- Copy class set of Astro Journals Lesson 10: Atmosphere and Temperature
- Copy a class set of Planetary Comparison Charts
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

**Differentiation:**

**Accommodations**
For students who may have special needs, use a more guided inquiry process.

**Advanced Extensions**
Have students set up multiple test planets with increasing levels of atmosphere (multiple layers of plastic wrap) and graph the results. Is the relationship linear?
1. **Review Habitable Zone and systems.**
   - Question: What role does the distance of a planet from its star play in the planet’s temperature?
     - Answer: The closer a planet is to its star, the higher its average temperature.
   - Question: What is the Habitable Zone?
     - Answer: The Habitable Zone is the distance from a star in which a planet could maintain liquid water on or near its surface.
   - Question: What would happen if a planet were closer to a star than to the Habitable Zone?
     - Answer: The planet would be too hot, and the water would be a gas (steam).
   - Question: What would happen if a planet orbited beyond the Habitable Zone?
     - Answer: The planet would be too cold, and any water present would be solid ice.
   - Question: Based on what we know so far, how would you describe the planetary temperature system?
     - Answer: The temperature depends on the type of star and the distance of the planet from that star.

2. **Bridge to this lesson.**
   - Question: When we looked at Venus, how similar was it to the Earth?
     - Answer: Venus was very similar, but the average temperatures of Earth and Venus are very different. In fact, Venus’ surface is so hot that it can melt lead.
   - Have students take out their Planetary Comparison Charts.
   - Question: Are there any planets closer to the Sun than Venus?
     - Answer: Yes, the planet closer to the Sun is Mercury.
   - Question: Based on what we’ve learned, how should Mercury’s temperature compare with Venus’ and why?
     - Answer: Since Mercury is closer to the sun, it should have a higher average temperature.
   - Question: Does Mercury have a higher average temperature?
     - Answer: No.
   - Question: How and why is this occurring?
     - Answer: This is occurring, because the system is incomplete. There are factors we have not yet considered.
   - Question: Let’s look at Venus and Earth again. Does Venus generally have larger or smaller values than Earth?
     - Answer: Venus generally has smaller values than Earth.
   - Question: Besides temperature, are there any that are larger?
     - Answer: Yes. Atmospheric mass is another value, which is larger.
3. Introduce the Scientific Question and purpose of the lesson.

- Question: How does atmosphere affect the planetary temperature system?
  - Students record their hypotheses in the Hypothesis/Prediction section of their Astro Journals.

- Question: Why do we want to explore how atmosphere affects a planet's temperature?
  - Answer: We want to understand all of the factors that affect a planet's temperature system and how they work together.

- Question: Why are we interested in the temperature of a planet?
  - Answer: The temperature of a planet determines its ability to maintain liquid water, which is essential for life.

1. Students design experiments that test their hypotheses.

- Question: How could we test your hypotheses?
  - Answer (Record student responses on chart paper. One way to test this in the classroom is to make a model and test the model to verify the hypotheses.)

- Question: If we were going to build a model of this system, what parts would we need, and what could we use to model them?
  - Answer: (Answers may vary. One possible experiment might be: a star represented by a light or lamp; the planet represented by a box; and the atmosphere represented by plastic wrap or some other clear covering.)

- Question: How will you know that your "atmosphere" affects the temperature of the system?
  - Answer: We'll need to compare it to another system with no "atmosphere". (If the above model is used, a second box and lamp can be used for comparison. Thermometers will be needed in each to measure temperatures.)

- Question: How will you know that the difference between the two systems is because of the "atmosphere"?
  - Answer: We'll need to make sure that the two situations we are comparing are exactly the same except for that one has an "atmosphere" and one doesn't.

  Note to Teacher: Be sure to discuss with students the importance of having everything exactly the same except for the atmosphere. These ideas can be discussed without even using the terms: "variables" and "controls".

2. Students plan and set up their experiments.

- Put students into groups to refine hypotheses and plan experiments to test them.
  - Review "testing for the hypothesis," and demonstrate how the materials, procedures, and data for the test will be recorded in the Astro Journal for this lesson.

  Note to Teacher: Make sure that the students are thinking in terms of data – what data they will be collecting, how they will be measuring it, and how that it is either going to confirm or refute their hypotheses.
• Have students share their hypotheses, and experiment plans.  
  Ask questions to help groups clarify aspects of their plan, but try to avoid giving them the answers.  
  • Sample questions might include:  
    • How does this experiment test your hypothesis?  
    • What specific data are you collecting?  
    • How will this data confirm or refute your hypothesis?  
    • How are you going to measure your data?  

Note to Teacher: Corrections should be focused on science process, not the correctness of the hypothesis. An incorrect hypothesis with a solid experimental plan is fine. A correct hypothesis without a solid experimental plan should be corrected.

3. Students should set up their experiments and record their Materials and Procedures in their Astro Journals.

**Explore** Day 2 - (approximately 20 minutes)

1. Students conduct their experiments in which they measure and record the temperature of their two systems over time.  
  Note to Teacher: If students have chosen an experiment that uses a good metaphor for atmosphere, they should observe that the temperature of the system with “atmosphere” is higher than the system without.

**Explain** (approximately 10 minutes)

1. Students fill out the Results and Conclusions sections of their Astro Journals.

2. Have students share their findings.  
   • Question: What did your experiment show about how the atmosphere of a planet affects its temperature? Why?  
   • Answer: The atmosphere causes the temperature to rise, because it traps heat.

3. Review the campfire metaphor and extend it to include atmosphere.  
   • Question: What happens when we move closer to a campfire?  
   • Answer: We feel warmer.  
   • Question: What is this modeling?  
   • Answer: It models the Habitable Zone. The campfire is like our Sun and we are like a planet.  
   • Question: Imagine you take a step away from the fire, but then put on a heavy parka. Now what happens to your temperature?  
   • Answer: You feel warmer. You could even be warmer than when you were closer to the fire.
• Question: So what does the parka symbolize or model?
  • Answer: The parka is like an atmosphere around a planet.

• Question: How is this like Venus and Mercury?
  • Answer: Even though Mercury is closer to the Sun, it is not as warm as Venus, because of Venus’ thick atmosphere.

**Extend/Apply (approximately 10 minutes)**

1. Have students draw a basic concept map of the planetary temperature system in their Astro Journal. (See Lesson 7 for a sample).

2. Physically model the system.
   • Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (can go up and down).
   • Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet. As I make some changes to this planet, make the appropriate change with your arm.

   • Say: O.K. You’re planet is starting to move closer to its star. What is happening to its temperature?
     • Answer: Arms go up.

   • Say: Now it’s moving farther away. What’s happening?
     • Answer: Arms go down.

   • Say: Now the star is changing. Its surface temperature is rising. What’s happening?
     • Answer: Arms go up.

   • Say: Now the atmosphere is disappearing. What’s happening?
     • Answer: Arms go down.

   • Keep changing parts to the system until everyone is correctly responding to the changes.

   • Say: Now, your goal is going to be to have a moderate temperature where your arm is out in front of you. What happens if the star type changes and becomes very hot?
     • Answer: Arms go up.

   • Say: What could you do to your system so that you could keep a moderate temperature?
     • Answer: The planet could be further away from the star, or there could be less of an atmosphere on the planet. (Move arms back to the middle position).

   • Say: What if your planet moves further away from the star?
     • Arms go down.

   • Say: What can you do to keep a moderate temperature?
     • Answer: The star could be hotter or there could be more of an atmosphere around the planet. (Move arms back to middle position).
• Say: Now, your atmosphere has become thinner. What’s happening?
  • Answer: Arms go up.
    Note to Teacher: Discuss with students what happens to temperature when there is a very thin atmosphere like Mars. Discuss that because there is so little atmosphere to trap the heat, as soon as the Sun goes down, heat escapes, and it becomes very cold. As a result, Mars experiences extreme temperature changes. Discuss that, thus, any life living on a planet would have to be able to stand big temperature changes.

• Say: What can you do to keep a moderate temperature?
  • Answer: We could have a cooler star or the planet could be closer to the star.

• Question: Does what the atmosphere is made of make a difference?
  • Answer: Yes. Certain gases trap more heat than other gases. (Venus is so hot, because it’s atmosphere is largely composed of Carbon Dioxide.)

• Question: Do planets actually change like this?
  • Answer: No.

• Question: Then why are we doing this?
  • Answer: To model the planetary temperature system.

Evaluate (approximately 10 minutes)

1. Have students share their responses to the Conclusion questions.

• Question: Why is atmosphere important to human life? How much of an atmosphere do we need? Why?
  • Answer: Atmosphere helps to trap heat, which helps to keep the temperature from becoming too hot or too cold. However, if we have too much of an atmosphere, or if the atmosphere is made of gases that trap too much heat, then the planet will become too hot for humans to live on.

• Question: What is needed for a planet to have the right temperature for human habitation?
  • Answer: In order for a planet to have the right temperature for human habitation, there must be: a moderate star; a planet that is orbiting at a distance where the heat from the star provides a temperature that allows water to be a liquid on the planet’s surface at all times; and an atmosphere that traps enough heat to maintain a stable temperature but not so much heat that the temperature would be too hot for liquid water.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
Part 3

Thinking in Systems | The Solar System | Planetary Temperature as a System | Atmosphere $\&$ Temperature | Atmospheric Mass | Disrupting the Systems

Name:  
Date:  

4. Data:

Astro Journal Lesson 10: Atmosphere and Temperature

Class/Period:  

1. Scientific Question: How does the atmosphere of a planet affect the planetary temperature system?

2. Hypothesis/Prediction: What do you think causes the change in the planetary temperature system? Why?

3. Materials: What materials will you use to test your hypothesis or prediction?
Astro Journal Lesson 10: Atmosphere and Temperature

Class/Period:

5. Results: How does the atmosphere of a planet affect the planetary temperature system? Why?

<table>
<thead>
<tr>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
</table>

6. Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis and modeling the atmosphere change your original ideas?

<table>
<thead>
<tr>
<th>Why is atmosphere important to human life? How much atmosphere do we need? Why?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>What is needed for a planet to have the right temperature for human habitation?</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
</tbody>
</table>
## Planetary Comparison Chart

<table>
<thead>
<tr>
<th>Planet</th>
<th>Mass (Earth = 1)</th>
<th>Diameter (R')</th>
<th>Density (g/m³)</th>
<th>Mass of Atmosphere</th>
<th>Atmospheric Force of Gravity (Earth = 1)</th>
<th>Average Temperature of Atmosphere (°C/°F)</th>
<th>Average Temperature of Surface (°C/°F)</th>
<th>Liquid Water</th>
<th>Mass of Liquid Water (g/cm³)</th>
<th>Force of Gravity of Liquid Water (Earth = 1)</th>
<th>Atmospheric Mass (g)</th>
<th>Disrupting the Systems</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>0.05</td>
<td>4,878 (2,439)</td>
<td>5,430</td>
<td>Argon, Neon, and Helium</td>
<td>0.38</td>
<td>Day: 350°C/662°F; Night: -170°C/-274°F</td>
<td>Too hot for surface water</td>
<td>too hot for surface water</td>
<td>0.002</td>
<td>5.53 x 10^4</td>
<td>variable</td>
<td></td>
</tr>
<tr>
<td>Venus</td>
<td>0.82</td>
<td>12,715 (6,052)</td>
<td>5,250</td>
<td>Carbon Dioxide</td>
<td>0.90</td>
<td>Day: 465°C/869°F; Night: 150°C/294°F</td>
<td>Too hot for surface water</td>
<td>5,430</td>
<td>0.001</td>
<td>1.41 x 10^4</td>
<td>4.4 x 10^14</td>
<td></td>
</tr>
<tr>
<td>Earth</td>
<td>1.00</td>
<td>12,104 (6,052)</td>
<td>5,520</td>
<td>Carbon Dioxide</td>
<td>1.00</td>
<td>Day: 25°C/77°F; Night: -12°C/-11°F</td>
<td>Too hot for liquid water</td>
<td>5,520</td>
<td>3.300</td>
<td>3.09 x 10^4</td>
<td>7.8 x 10^16</td>
<td></td>
</tr>
<tr>
<td>Moon</td>
<td>0.01</td>
<td>3,476 (1,738)</td>
<td>3,940</td>
<td>Carbon Dioxide</td>
<td>0.17</td>
<td>Day: 20°C/68°F; Night: -160°C/-274°F</td>
<td>No liquid water</td>
<td>3,940</td>
<td>1.314</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Mars</td>
<td>0.11</td>
<td>6,790 (3,395)</td>
<td>3,940</td>
<td>Carbon Dioxide</td>
<td>0.39</td>
<td>Day: -25°C/-9°F; Night: -180°C/-292°F</td>
<td>Mars may have once had surface water; it now has been detected at the North Pole.</td>
<td>3,940</td>
<td>1.314</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Jupiter</td>
<td>318</td>
<td>142,796 (66,380)</td>
<td>1,314</td>
<td>Hydrogen, Helium</td>
<td>0.93</td>
<td>Day: -10°C/-14°F; Night: -230°C/-376°F</td>
<td>Some water vapor and ice crystals in the atmosphere</td>
<td>1,314</td>
<td>1.314</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Saturn</td>
<td>95</td>
<td>120,660 (60,330)</td>
<td>1,290</td>
<td>Hydrogen, Helium</td>
<td>0.39</td>
<td>Day: -10°C/-14°F; Night: -230°C/-376°F</td>
<td>Some water vapor and ice crystals in the atmosphere</td>
<td>1,290</td>
<td>1.290</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Uranus</td>
<td>17</td>
<td>49,528 (25,764)</td>
<td>1,640</td>
<td>Hydrogen, Helium</td>
<td>0.93</td>
<td>Day: -10°C/-14°F; Night: -230°C/-376°F</td>
<td>Some water vapor and ice crystals in the atmosphere</td>
<td>1,640</td>
<td>1.640</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Neptune</td>
<td>17</td>
<td>49,528 (25,764)</td>
<td>1,640</td>
<td>Hydrogen, Helium</td>
<td>0.93</td>
<td>Day: -10°C/-14°F; Night: -230°C/-376°F</td>
<td>Some water vapor and ice crystals in the atmosphere</td>
<td>1,640</td>
<td>1.640</td>
<td>2.6 x 10^2</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
<tr>
<td>Pluto</td>
<td>0.002</td>
<td>2,330 (1,150)</td>
<td>2,030</td>
<td>Hydrogen, Helium</td>
<td>2.03</td>
<td>Day: -10°C/-14°F; Night: -230°C/-376°F</td>
<td>Any water is frozen as ice.</td>
<td>2,330</td>
<td>2.330</td>
<td>variable</td>
<td>7.4 x 10^15</td>
<td></td>
</tr>
</tbody>
</table>

Notes:
- Any water is frozen as ice.
- Any mass and diameter values in parentheses refer to current estimates.
- Mass and diameter values are given for comparison purposes only and may not reflect current scientific understanding.


Students explore the planetary temperature system. They explore how each aspect (e.g., mass, temperature and gravity) influence the system and the consequences of disrupting that system.

Main Lesson Concept: The amount of atmosphere on a planet depends on the planet’s gravity, which is determined by the planet’s mass.

Scientific Question: What determines the amount of atmosphere on a planet?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will explain and illustrate how planetary mass affects atmosphere to effect a change in the temperature of a planet.</td>
<td>Meets: 2061: 11A 6-8 #2</td>
</tr>
<tr>
<td></td>
<td>NSES: UCP K-12 #1</td>
</tr>
<tr>
<td>Students will explain why 1/4 to 4 times Earth’s mass is a requirement for habitability.</td>
<td>Addresses: NSES: A 5-8 #1</td>
</tr>
<tr>
<td></td>
<td>NCTM: 2, 5, 9</td>
</tr>
</tbody>
</table>

Assessment: Write-up in Astro Journal.

Abstract of Lesson: Students learn to compare characteristics from the Planetary Comparison Chart to see if there is a relationship between the characteristics of the planets. They use that knowledge to figure out which characteristics have a strong relationship with atmospheric mass. When the results are not completely conclusive, the students explore possible causes of discrepancies in the data. They conclude that gravity, mass and diameter all have a role in determining atmospheric mass.

Prerequisite Concepts:
- Atmosphere is the blanket of gases that surrounds some planets and moons
- Atmosphere traps heat, which increases and sustains the temperature of the planet. (Lesson 10)
- A system consists of many parts that usually influence each other and can be part of another system. (Lesson 7)
- Temperature measures the motion of molecules in a substance. (Lesson 6)
- Mass is the measure of the quantity of matter.
- Gravity is a force of attraction that exists between objects. The greater the mass, the greater its gravitational pull.

Major Concepts:
- Atmospheric mass is the amount of atmosphere on a planet.
- Gravity is a function of mass and diameter.
- Gravity is a major factor in determining the amount of atmosphere around a planet.
Suggested Timeline (45 minute periods):
Day 1: Engage and Explore Sections
Day 2: Explain
Day 3: Extend/Apply and Evaluate Sections

Materials & Equipment:
- A class set of Astro Journals Lesson 11: Atmospheric Mass*
- A class set of Planetary Temperature System Concept Map Activity
- A class set of Planetary Comparison Charts
- A class set of the Gravity and Atmosphere Reading
- Chart Paper

Preparation:
- Gather materials.
- Duplicate Astro Journals, Planetary Comparison Charts and Gravity, Planetary Temperature System Concept Map Activity and Atmosphere Reading.
- Put up distance vs. temperature chart (See step 2)
- Prepare chart paper with major concept of the lesson to post at the end of the lesson.

*Note to Teacher: A generic Astro Journal and Scientific Rubric are included at the end of this part. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:

Accommodations
See the following note to teacher about a simpler version of this lesson that would be more appropriate for fifth or sixth grade students.

Advanced Extensions
Students use the comparing technique presented in the lesson and the planetary comparison chart (and any other planetary data that they can find) to look for interesting patterns, ask questions, and find answers about other relationships.

Variation:
Note to Teacher: This lesson is most appropriate for seventh and eighth graders. Some advanced sixth graders might benefit from it as well. For others, do the following sequence.

1. Drop a book on the ground.
   - Question: Why did this book go in the direction that it did?
   - Answer: Gravity.

   - Question: So gravity holds matter to the surface of Earth. We just observed it holding solid matter. Does it also hold liquid matter?
   - Answer: Yes.

   - Question: Does it hold a gas?
   - Answer: Yes.

Note to Teacher: Students may debate this. Allow them to. Have them use the language of molecular bonds and motion that they learned in Part 2. Even though the molecules have more molecular motion and are moving more quickly and freely, there is still a force of attraction between them and the planet. It will also be important to keep reminding them that gravity exists between pieces of matter.
Question: Let’s go back to the book for a second. Is Earth pulling on the book or is the book pulling on Earth?
Answer: Both.

Question: What else does gravity hold to the Earth?
Answer: Gases. Water.

Question: Do all planets have the same amount of gravity? How do you know?
Answer: No. The moon has less gravity. That is why the astronauts bounce when they walk there.

Question: What determines the amount of gravity a planet has?
Answer: The mass of a planet. The larger the mass, the greater the gravity.

Question: So how do mass and gravity change what the planet has on its surface?
Answer: More gases are attracted to larger planets. Fewer gases are attracted to smaller planets. Therefore, the larger a planet, the more atmosphere it will have.

Engage (approximately 20 minutes)

1. Review the planetary temperature system.
   Question: So far, what are the key parts of the planetary temperature system that we've explored?
   Answer: We have explored star type, distance from star and atmosphere.

   Question: So, given planets surrounding the same star, what would be the significant parts?
   Answer: Distance and atmosphere.

   Question: What would the general trend be for the distance from the star?
   Answer: The closer to the star the planet is, the higher its average temperature

   Question: Is there any way we could test that?
   Answer: We could look at planets in our Solar System and compare their temperatures and distances from the Sun.

2. Model and provide guided practice of observing relationships.
   Refer to distance vs. temperature chart.
   Say: Here we have two listings of the planets. One is based on the distance of the planets from the Sun and goes from the closest planet to the Sun to the most distant planet. The other list is based on the average temperatures of the planets and goes from the highest average temperature to the lowest.

<table>
<thead>
<tr>
<th>Distance From Sun</th>
<th>Average Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>Venus</td>
</tr>
<tr>
<td>Venus</td>
<td>Mercury</td>
</tr>
<tr>
<td>Earth</td>
<td>Earth</td>
</tr>
<tr>
<td>Mars</td>
<td>Mars</td>
</tr>
<tr>
<td>Jupiter</td>
<td>Jupiter</td>
</tr>
<tr>
<td>Saturn</td>
<td>Saturn</td>
</tr>
<tr>
<td>Uranus</td>
<td>Uranus</td>
</tr>
<tr>
<td>Neptune</td>
<td>Pluto</td>
</tr>
<tr>
<td>Pluto</td>
<td>Neptune</td>
</tr>
</tbody>
</table>
Question: When you look at these two lists, what do you notice?
Answer: Many of the planets line up exactly with themselves in the other list. Others are just one line different.

Question: Why does this happen?
Answer: This happens, because there is a relationship between the temperature of a planet and its distance from its star (in this case, the Sun).

Say: Let’s see if we can’t make this relationship look a little clearer.
Draw a line from each planet from one list, to itself in the other list so that your chart looks like the following.

<table>
<thead>
<tr>
<th>Distance from Sun</th>
<th>Average Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>Venus</td>
</tr>
<tr>
<td>Venus</td>
<td>Mercury</td>
</tr>
<tr>
<td>Earth</td>
<td>Earth</td>
</tr>
<tr>
<td>Mars</td>
<td>Mars</td>
</tr>
<tr>
<td>Jupiter</td>
<td>Jupiter</td>
</tr>
<tr>
<td>Saturn</td>
<td>Saturn</td>
</tr>
<tr>
<td>Uranus</td>
<td>Uranus</td>
</tr>
<tr>
<td>Neptune</td>
<td>Pluto</td>
</tr>
<tr>
<td>Pluto</td>
<td>Neptune</td>
</tr>
</tbody>
</table>

Question: There are only two places where the connecting lines cross. What does that say to you about the strength of the relationship between a planet’s distance from its star and its average temperature?
Answer: It’s a strong relationship.

Have students list the planets in order by force of gravity from least to greatest.
Answer: Pluto, Mercury, Mars, Venus, Uranus, Earth, Saturn, Neptune, Jupiter

Have the students compare the ‘force of gravity’ list with the ‘distance from sun list’ by connecting each planet in the two lists.

Question: How many lines cross each other?
Answer: Many.

Note to Teacher: Depending on how the lines are drawn, the exact number will vary. The important point is that there are many lines that cross so there is little relationship between these characteristics. If your students are comfortable with the term “variables,” you may use it with them.

Have students reverse the order of one of the lists and redo the comparison.
Note to Teacher: If it is appropriate for your students, you can talk about direct and inverse relationships here.

Question: How many lines cross each other?
Answer: Again, many.

Question: What do these two comparisons suggest to you about the relationship between a planet’s distance from its star and the force of gravity on that planet?
Answer: There’s little relationship.
• Say: What we are doing with these lists can be done much more precisely with certain mathematical equations. We can see general trends in the relationships between certain characteristics by using this method.

• Question: Given all the comparisons we’ve made so far, what do you think is the general rule for comparing lists in this way?
  • Answer: The fewer lines that cross, the stronger the relationship.
  Note to Teacher: What we’re approximating here is correlation. This topic is beyond most fifth through eighth graders, but by counting the points at which the lines cross, they can at least see that certain characteristics are more or less related. That should be sufficient for the purposes of this lesson.

3. Introduce the Scientific Question and purpose of the lesson.
• Tell the students that they’ll be using this method to explore this lesson’s scientific question.
• Scientific Question: What determines the amount of atmosphere on a planet?

• Question: Why do we want to know what determines the amount of atmosphere on a planet?
  • Answer: Because atmosphere affects the temperature.

• Question: Why are we interested in temperature?
  • Answer: Temperature determines the presence of liquid water.

• Question: Why do we want liquid water?
  • Answer: Humans need it to survive.

Explore (approximately 25 minutes)

1. Have students predict the characteristics from the Planetary Comparison Chart that they think will have a relationship with the atmospheric mass characteristic. They should record their predictions under the Hypothesis/Prediction section in their Astro Journals.

   Note to Teacher: Since we do not have atmospheric mass for Pluto, students should include the moon in their list instead.

2. Students test their predictions by setting up comparisons between atmospheric mass and other characteristics, connecting planets, and counting line crosses. They fill out the Materials, Procedure and Data sections of their Astro Journals.
1. **Students share their results with a partner or small group and discuss what they think the data mean.**

2. **Approximate results are as follows:**
   
   Note to Teacher: These numbers include the use of the moon in the lists. If the students don’t include the moon in their lists, the numbers may be different. Remember, the numbers don’t need to be exact, it’s the trend that’s important.
   
   - Atmospheric Mass and Gravity – 5 line crosses
   - Atmospheric Mass and Mass (Planet) – 3 line crosses
   - Atmospheric Mass and Diameter (Radius) – 2 line crosses
   - Atmospheric Mass and Density – many line crosses

3. **Students fill in the Results sections of their Astro Journals**

4. **Question: So what do these results mean?**
   
   Note to Teacher: This is where it gets complicated. Gravity is the force that retains atmosphere, but the relationship between it and atmospheric mass does not appear to be that strong. Adding to the complexity is the fact that both mass and diameter have strong relationships with atmospheric mass. Since gravity is a function of mass and diameter, the comparison between gravity and atmospheric mass seems less comprehensible. This is an opportunity to explore with students the fact that scientists often face this very situation. Rather than finding out that their hypotheses or predictions are exactly right or exactly wrong, they sometimes have to think about their results and what those results really mean. The following questions are to get the students thinking about possible ways of analyzing their results.

   List student thoughts on board/chart paper
   
   - Question: What kind of relationship did gravity have with atmospheric mass?
     - Answer: not that strong – 5 line crosses

   - Question: What kind of relationship did mass have with atmospheric mass?
     - Answer: pretty strong – 3 line crosses

   - Question: What kind of relationship did diameter (radius) have with atmospheric mass?
     - Answer: pretty strong – 2 line crosses

   - Question: What determines the gravity of a body?
     - Answer: mass and radius (diameter)
**Question: So what is going on?**

**Record student responses.**

*Note to Teacher: There are a few possibilities here.*

- There may be a problem with the data (accuracy).
- There may be not be enough data points to work with (if there were more planets, the trends might be clearer).
- There may be a problem with the procedure (the line cross method definitely does have limits).
- There may be problems with the interpretation (maybe the difference between two or three line crosses and five line crosses isn’t significant).
- There may be a factor that has not been taken into account.
- Atmospheric mass may be caused by multiple factors, so that there is not a one to one relationship.
- There may be other possible problems.

Regardless of the reason for the problem, the process for resolving the problem is to examine all parts of the experiment and test further.

*Some questions to suggest these possibilities to students include:*

- How do we know our data is accurate?
- If we had more planets to compare in the lists, would this make the data more clear? Why?
- Could there be a problem with the procedure we used to compare the lists?
- Is there really a difference between two to three line crosses and five? How do we know?
- Could there be something else affecting one or more of the characteristics that we haven’t considered?

**Question: What could we do to get a more conclusive answer?**

*Answer: Do more tests in order to increase the amount of data to arrive at a conclusive answer.*

5. Have students fill out the Conclusion sections of their Astro Journals.

6. Read the Gravity and Atmosphere Reading with students.

Have them answer the comprehension questions.

7. Tell students that gravity is what holds the atmosphere on a planet:

*Although, there are other factors that have an influence (which may partially account for the odd results of the comparisons). One factor that can influence atmospheric mass is the gases that were available when the planet was formed. Gravity is a function of mass and density, so both influence the amount of atmosphere a planet will have.*

8. Discuss the importance of having the right amount of gravity.

- **Question: What happens if we have too much atmosphere?**
  - **Answer: It will be too hot which will cause ice caps to melt and then water to evaporate.**

- **Question: What happens if we have too little atmosphere?**
  - **Answer: There won’t be greenhouse gases to trap heat, which will cause cooler temperatures that could freeze any water, if present. Water vapor can also escape so that there might not be water.**
1. **Have students physically model the planetary temperature system.**  
   Have the students stand so that they can have one arm out to act as a thermometer. They should start with their arm in a middle position (can go up and down).
   - Say: Your arm is going to function like a thermometer. It is currently the temperature of a planet. As I make some changes to this planet, make the appropriate change with your arm.
   - Say: O.K. You're planet is starting to move closer to its star. What is happening to its temperature?  
     • Answer: Arms go up.
   - Say: Now it's moving farther away. What's happening?  
     • Answer: Arms go down.
   - Say: Now the star is changing. Its surface temperature is decreasing. What's happening?  
     • Answer: Arms go down.
   - Say: Now the mass of the planet is increasing. What's happening?  
     • Answer: Arms go up.
   - Question: Why does the temperature increase when we increased mass?  
     • Answer: The gravity of the planet increases which attracts more atmosphere trapping more heat.
   - Say: Now the radius (diameter) of the planet is shrinking. What's happening?  
     • Answer: Arms go down.
   - Question: Why does temperature decrease when we decreased the radius (diameter) of the planet?  
     • Answer: The gravity of the planet decreases, so greenhouse gases escape trapping less heat.

Keep changing parts to the system (star type/temperature, distance from star, gravity, mass, diameter) until everyone is correctly responding to the changes.

   - Question: Do planets and stars actually change like this?  
     • Answer: No.
   - Question: Then why are we doing this?  
     • Answer: To model the planetary temperature system and to show how a change in one part of the system affects the temperature.
Evaluate  
(approximately 25 minutes)

1. Have students draw a concept map of the planetary temperature system that identifies the parts of the system and the sub-system, which determines atmosphere. Have them explain this system using the characteristics of a system in their explanation. The concept map should look something like the following diagram.

   ![Concept Map Diagram]

2. Discuss with students their Astro Journal results and conclusions. Ensure that they have a solid understanding of the importance of having the right amount of gravity. Assess their understanding of this concept.

   - Question: If gravity determines the amount of atmosphere on a planet, what determines the amount of gravity we have?
   - Answer: Mass is a major factor that determines gravity. Radius is also a factor. So if you predicted that, gravity, mass or radius determines the amount of atmosphere on a planet, you were right.

   Note to Teacher: Relate this to something with which students might have experience, such as why the astronauts bounce on the moon or what we would weigh on Jupiter. Students will likely see a relationship between the size or mass of a planet and its gravity.

   - Question: Why do we need to have a planet that is between 1/4 and 4 times Earth’s mass?
   - Answer: We must have the right amount of gravity to hold onto the right atmosphere. Too much mass or gravity would attract too many greenhouse gases trapping heat and causing water to evaporate. Too little mass or gravity would attract too little greenhouse gases so that heat would not be trapped and water would freeze or escape.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
Astro Journal Lesson 11: Atmospheric Mass

Class/Period:

1. Scientific Question: What determines the amount of atmosphere on a planet?

2. Hypothesis/Prediction: What do you think determines the amount of atmosphere on a planet? Why?

3. Materials: Where did you obtain the data for this activity?

4. Procedure: What steps will you take to compare characteristics?

Name:

Date:
Astro Journal Lesson 11: Atmospheric Mass

<table>
<thead>
<tr>
<th>Class/Period</th>
<th>Name:</th>
<th>Date:</th>
</tr>
</thead>
</table>

5. **Data Collection**: Show the relationships between planets using different factors.

6. **Results**: What determines the amount of atmosphere on a planet?

7. **Conclusions**: Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction and drawing relationships change your original ideas?
**Planetary Temperature System Concept Map Activity**

On a separate sheet of paper, draw a concept map of the planetary temperature system and sub-systems and explain how the different parts of the system influence each other in determining a planet’s temperature. Explanations must include references to the characteristics of systems:

1. Explain what the parts of the system and sub-systems are and how they influence each other.
2. Explain what happens to the temperature if one part changes. Give specific examples.
3. Explain the sub-system(s) contained in the system.
4. In particular, explain the role of atmosphere in determining the temperature of a planet.
5. Explain why it is necessary for humans to have a planet that is between 1/4 and 4 times Earth’s mass.

Your concept map will be evaluated using the following rubric.

<table>
<thead>
<tr>
<th>Score</th>
<th>Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Concept map clearly and accurately explains the planetary temperature system.</td>
</tr>
<tr>
<td></td>
<td>Concept map has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed explanation.</td>
</tr>
<tr>
<td>3</td>
<td>Concept map clearly and accurately explains the planetary temperature system.</td>
</tr>
<tr>
<td></td>
<td>Concept map has all required parts, makes specific references to examples, and uses good reasoning in explanations.</td>
</tr>
<tr>
<td>2</td>
<td>Concept map is not completely clear or accurate in explaining how the planetary temperature system.</td>
</tr>
<tr>
<td></td>
<td>Concept map has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.</td>
</tr>
<tr>
<td>1</td>
<td>Concept map is not clear or accurate in explaining the planetary temperature system.</td>
</tr>
<tr>
<td></td>
<td>Concept map is not clear or accurate in explaining how the Solar System is a system and is missing several parts, makes few specific references to examples, and uses little or no good reasoning.</td>
</tr>
</tbody>
</table>
Gravity and Atmosphere Reading

What is gravity?
Gravity is a force of attraction that exists between objects. Gravity is related to the mass and density of an object or planet. The greater a planet’s mass, the greater its gravity.

What does gravity have to do with atmosphere?
A certain amount of gravity is needed to hold on to the kind of atmosphere we have on Earth. With less gravity, a planet cannot hold on to the atmosphere that we need to survive. With more gravity, the planet attracts more atmosphere. This atmosphere would trap a lot of heat and cause the temperature to rise very high. In time, this would cause the polar ice caps to melt, submerging much of the land and causing the oceans to evaporate. A planet with more gravity would also attract poisonous gases in its atmosphere.

Is gravity the only factor that affects having the right kind of atmosphere?
Having the right amount of mass and the right amount of gravity doesn’t guarantee the planet will have the right kind of atmosphere. The atmosphere may not be made of the right amount and kind of elements that humans need. Venus is a good example of this. Although Venus’s mass is very close to Earth’s mass, Venus’s surface temperature is hot enough to melt lead! This is because Venus’s atmosphere is mostly carbon dioxide, which traps heat from the Sun instead of letting the heat bounce back into space. Earth’s atmosphere is mostly nitrogen and oxygen.

Questions
(Answer on a separate sheet of paper)

1. What is gravity?
2. How is gravity related to atmosphere?
3. What happens to planets with large mass?
4. What happens to planets with small mass?
5. Can you have the right mass but still have the wrong atmosphere for human survival? Explain.
## Planetary Comparison Chart

<table>
<thead>
<tr>
<th>Planet</th>
<th>Atmosphere</th>
<th>Mass</th>
<th>Diameter</th>
<th>Density</th>
<th>Liquid Water</th>
<th>Average Temperature</th>
<th>Force of Gravity</th>
<th>Atmospheric Mass</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Earth = 1</td>
<td>(Radius)</td>
<td>gm/m³</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mercury</td>
<td>very little: argon, neon and helium</td>
<td>0.06</td>
<td>4,878</td>
<td>5,430</td>
<td>too hot for surface water</td>
<td>day: 350°C/662°F</td>
<td>0.38</td>
<td>2.03 x 10⁴</td>
</tr>
<tr>
<td>Venus</td>
<td>carbon dioxide</td>
<td>0.82</td>
<td>12,104</td>
<td>5,250</td>
<td>too hot for surface water</td>
<td>465°C/869°F</td>
<td>0.90</td>
<td>1.41 x 10²¹</td>
</tr>
<tr>
<td>Earth</td>
<td>nitrogen, oxygen</td>
<td>1.00</td>
<td>12,755</td>
<td>5,520</td>
<td>liquid water on the surface</td>
<td>15°C/59°F</td>
<td>1.00</td>
<td>5.33 x 10⁸</td>
</tr>
<tr>
<td>Moon</td>
<td>none</td>
<td>0.01</td>
<td>3,476</td>
<td>3,300</td>
<td>no liquid water</td>
<td>sunlit side: 134°C/273°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>dark side: -153°C/-243°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mars</td>
<td>carbon dioxide</td>
<td>0.11</td>
<td>6,790</td>
<td>3,940</td>
<td>Mars may have once had surface water, but doesn’t now. Ice has been detected at the North Pole.</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>-23°C/-9.4°F</td>
<td>0.39</td>
<td>3.09 x 10¹⁴</td>
</tr>
<tr>
<td>Jupiter</td>
<td>hydrogen, helium</td>
<td>318</td>
<td>142,796</td>
<td>1,314</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-150°C/-238°F</td>
<td>2.53</td>
<td>2.6 x 10²²</td>
</tr>
<tr>
<td>Saturn</td>
<td>hydrogen, helium</td>
<td>95</td>
<td>120,660</td>
<td>690</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-180°C/-292°F</td>
<td>1.06</td>
<td>4.4 x 10²²</td>
</tr>
<tr>
<td>Uranus</td>
<td>hydrogen, helium</td>
<td>15</td>
<td>51,118</td>
<td>1,290</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-221°C/-391°F</td>
<td>0.93</td>
<td>7.8 x 10²¹</td>
</tr>
<tr>
<td>Neptune</td>
<td>hydrogen, helium</td>
<td>17</td>
<td>49,528</td>
<td>1,640</td>
<td>some water vapor and ice crystals in the atmosphere</td>
<td>-235°C/-391°F</td>
<td>1.18</td>
<td>7.4 x 10²¹</td>
</tr>
<tr>
<td>Pluto</td>
<td>methane</td>
<td>0.002</td>
<td>2,300</td>
<td>2,030</td>
<td>Any water is frozen as ice.</td>
<td>-220°C/-364°F</td>
<td>0.07</td>
<td>variable</td>
</tr>
</tbody>
</table>

Any water is frozen as ice.
Lesson 12: Disrupting the System

Students explore the planetary temperature system. They conduct in-depth exploration into how each aspect of the system influences the planetary system and the consequences of disrupting that system.

**Main Lesson Concept:** If Jupiter were in an elliptical orbit at 1 AU, it could cause a change in Earth’s orbit, which would have consequences for the planetary temperature system.

**Scientific Question:** What could happen if Jupiter were in an elliptical orbit at 1 AU?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students explain how a planet’s orbit could be disrupted.</td>
<td>Meets: 2061: IA 6-8 #2</td>
</tr>
<tr>
<td></td>
<td>NSES: UCP K-12 #1</td>
</tr>
<tr>
<td>Students explore the implications of such a disruption on the planetary</td>
<td>Addresses: NSES: A 5-8 #1</td>
</tr>
<tr>
<td>temperature system and on human habitability.</td>
<td>ISTE: 3, 5</td>
</tr>
</tbody>
</table>

**Assessment**  
Jupiter’s in illustration or animation form.

**Abstract of Lesson**  
Students explore what could happen to the Earth if Jupiter’s orbit were different. They illustrate or animate the possibilities.

**Prerequisite Concepts**
- Mass is the measure of the quantity of matter.
- Gravity is a force of attraction that exists between objects. The greater the mass the greater its gravitational pull.
- An orbit is the path of an object as it moves around another object because of gravity. (Lesson 8)
- The Sun’s gravitational pull holds Earth and other planets in their orbits, just as the planets’ gravitational pull keeps their moons in orbit around them.
- A system consists of many parts that usually influence each other. (Lesson 7)

**Major Concepts**
- A disruption to a system such as the planetary temperature system can disrupt its ability to maintain a temperature suitable for human life.
Suggested Timeline (45 minute periods):
Day 1: Engage, Explore and Explain Sections
Days 2 – 6 (Depending on Project Choice): Extend/Apply Sections
Final Day: Evaluation for Part 3

Materials and Equipment:
• A class set of Jupiter’s Orbits Diagram Student Version
• An over head of Jupiter’s Orbit’s Diagram Teacher Version
• A class set of Jupiter and Earth cut-outs 1
• Chart paper
• A class set of Disrupting Jupiter’s Orbit Activity
• (optional) One Jupiter Orbit’s Diagram to scale printed and taped

Preparation:
• Gather materials.
• Duplicate Jupiter’s Orbits Diagram Student Version and Disrupting Jupiter’s Orbit Activity.
• Make an overhead transparency of the Jupiter’s Orbits Diagram (Teacher Version).
• Cut out the smallest planets from the Jupiter and Earth cut-outs 1 for Explore, Step 1.
• Check the link for the optional activity in Explore, Step 2.
• Prepare chart paper with major concept of the lesson to post at the end of the lesson.
• (optional) Print the nine-page Jupiter Orbit’s Diagram to scale, tape and display on a wall in your classroom.

Differentiation:

Accommodations
Assign students to heterogeneous groups for projects.

Advanced Extensions
If the students have access to a gravity simulation program, they could try to model the Jupiter/Earth relationship in it.
(See Explore, Step 2)
Engage (approximately 15 minutes)

1. **Review the planetary temperature system and introduce the purpose.**
   - Do the temperature modeling activity from Lesson 11 (Extend/Apply Section)
   - Be sure to change all of the characteristics: star type, distance from star, atmosphere, planetary mass, and diameter.
   - **Question:** Why is it important that the planet’s temperature system remain stable?
     - **Answer:** We couldn’t survive if the system were disrupted.
   - **Say:** Today we’re going to look at things that might disrupt the system so we can better understand how our system remains stable.

2. **Bridge to this lesson.**
   - **Say:** Let’s change things around a little bit. I’m going to give you different scenarios for planetary system change. (Model) You should respond with the same arm movements. Reset your arms to the neutral position.
   - **Say:** The star that your planet orbits is growing older. It is changing from a yellow Main Sequence star to a red giant. What happens?
     - **Answer:** Arms go up.
   - **Question:** Over time, what is likely to happen to water on this planet?
     - **Answer:** It will boil off into steam.
   - **Question:** How will that effect the ability of the planet to support human life?
     - **Answer:** It will limit it.
   - **Have students reset their arms to neutral.**
   - **Say:** Let’s assume now that your planet’s star is yellow and stable again. Now, however, something is happening on your planet that is putting more gas into the atmosphere. Not only is the atmospheric mass increasing, but also the gases are greenhouse gases. They retain more heat than other types of gases.
     - **Note to Teacher:** There are several possible sources for such gases including volcanic eruptions. Use what you’ve done with your students to be more specific if you want. What’s happening?
     - **Answer:** Arms go up.
   - **Question:** Over time, what is likely to happen to water on this planet?
     - **Answer:** It will boil off into steam.
   - **Question:** How will that effect the ability of the planet to support human life?
     - **Answer:** It will limit it.
     - **Students may drop their arms.**
   - **Question:** Is there any way for a planet to change its distance from its star?
     - **Record student responses.**
   - **Question:** What holds the parts of the Solar System together?
     - **Answer:** gravity
• Question: What causes gravity?
  • Answer: The mass of the bodies.

• Question: What could disrupt the gravity between two bodies with great mass?
  • Answer: Another body with great mass.

3. **Introduce the Scientific Question:**
   • Question: What could happen if Jupiter were in a highly elliptical orbit at 1 AU?

---

**Explore** (approximately 15 minutes)

1. **Address the misconception of the shape of Earth’s orbit.**

   **MISCONCEPTION:**
   Because of the way our Solar System is often depicted in images, a commonly held misconception is that the planets in our Solar System are in highly elliptical orbits. The reality is that their orbits are near circular. This is an important point for Earth’s habitability, since it helps to maintain a moderate temperature. To bring out this misconception, draw several diagrams of the Earth’s orbit around the Sun as follows:
   - Earth is in a highly elliptical orbit with the Sun in the middle.
   - Earth is in a near circular orbit with the Sun in the middle.
   - Earth is in a highly elliptical orbit coming very close to the Sun on one side.

   Ask students which diagram is closest to the Earth’s actual orbit and why they think so. After some discussion, point out that the circular orbit is the closest, but that when pictures in books depict the Solar System from the side, it makes the orbits look very elliptical. Explain that the orbits of the planets in our Solar System are, in fact, elliptical. However, they tend to be very close to circles. When we refer to elliptical orbits in this lesson and in the multimedia, we are referring to highly elliptical orbits as have been observed of planets in other systems or of comets.

2. **Put Jupiter’s Orbits Diagram onto overhead**
   - Tell the students that the diagram shows Earth’s actual orbit, Jupiter’s actual orbit and a hypothetical (made up, but possible) elliptical orbit for Jupiter.
   - Put the cut out Earth onto the diagram and demonstrate the orbit of Earth around the Sun.
MISCONCEPTION:

There are many commonly held misconceptions regarding the size and distances of the planets due to the difficulty of portraying these to scale. It is important to draw students’ attention to these misconceptions as modeled in the following discussion and activities.

• Question: Do you think this diagram is to scale? Why or why not?
  • Answer: The orbits are to scale, but the planets and the Sun are not. We would not be able to see the Sun and planets if they were drawn to scale. Since Jupiter is about ten times the diameter of Earth, and the Sun is about ten times the diameter of Jupiter, the Sun would need to be 500 times smaller!

• Question: If Jupiter is about ten times the diameter of Earth, and the Sun is about ten times the diameter of the Sun, how much smaller would they need to be at this scale compared to the Sun?
  • Answer: Jupiter would need to be 5,000 times smaller than the current diameter of the Sun, and Earth would need to be 50,000 times smaller than the current diameter of the Sun.

Note to Teacher: To show the actual diameters to scale, have students draw an Earth that is one inch in diameter, a Jupiter that is ten inches in diameter, and ask what the size the Sun would be. Students will quickly see that to draw a Sun at a diameter of one hundred inches would be very difficult. To show a scale diagram of the orbits, assemble the nine-page Jupiter Orbit’s Diagram to scale included at the end of this lesson. The sun will be to scale, but the planets will not be.

• Say: It’s important when presenting an illustration to inform the viewer whether or not the image is to scale. In this case, the orbits are to scale. The size of the planets and the Sun are not.

• Add the cut out Jupiter to the diagram on its real orbit and demonstrate its movement around the Sun.

• Question: What is holding the parts of the Solar System together?
  • Answer: Gravity.

• Question: Could there be any times when Jupiter and Earth were being pulled towards each other by gravity? If so, when?
  • Answer: Yes, when the planets’ orbits bring them in line with each other.

• Have a student demonstrate on the overhead.

• Move Jupiter onto the elliptical orbit. Demonstrate its movement.

• Question: If Jupiter were on this orbit, what would happen to it in relation to Earth?
  • Answer: It would move closer to Earth.

• Have a student demonstrate on the overhead.

• Question: What would happen to the attraction between the planets as they got closer?
  • Answer: The attraction would increase.

• If Earth is not already between the Sun and Jupiter, move it there now.

• Question: What is Earth being attracted to in this situation?
  • Answer: Both Jupiter and the Sun.

• Question: What could happen to the Earth’s orbit?
  • Answer: Earth could be pulled out of its orbit.

3. (Optional) Engage students in the following gravity simulator exploration.

• Question: Could we use an orrery (a mechanical model of the Solar System) to model this possibility? Why or why not?
  • Answer: We couldn’t because an orrery is based on the known, real movement of the planets.
Question: In the real Solar System, what holds the planets together?
Answer: Gravity.

Question: What would it take for a computer program to be able to model the Solar System and make changes to it?
Answer: It would have to model gravity.

The following link goes to "Gravitation 3.8" a web page with a Java applet that simulates gravity. While students are working on their projects, they can rotate through and experiment with the program. http://arachnoid.com/gravitation/

http://burtleburtle.net/bob/java/orbit/ also has an orbit simulator written in Java, but it is mostly for demonstration purposes. This link, http://burtleburtle.net/bob/physics/orbit101.html, has several demonstrations, but they can't be altered by students. The text is for high level physics students.

Explain (approximately 15 minutes)

1. Discuss the possible effects of Earth being pulled out of its orbit.
   - Question: If Earth were pulled out of its orbit, what do you think could happen?
   - Record student responses
   Possible Outcomes:
   - Earth could be ejected from the Solar System.
   - Earth could be sent into the Sun.
   - Earth could become a moon of Jupiter.
   - Earth could be pulled into Jupiter.
   - Earth could reestablish an orbit with the Sun at a greater distance from the Sun.
   - Earth's orbit could become highly elliptical.

Extend/Apply (1 to 4 Class Periods Depending on Project)

1. Students illustrate and animate the disruption to the planetary temperature system.
   - Put students into groups.
   - Assign or have each group choose a potential outcome to illustrate or animate. This activity has two options, a series of illustrations or an animation that uses a computer, some free programs, and a digital camera. With a little ingenuity, other methods of creating the animations can be used. If the animation activity is not doable, the series of illustrations or a flipbook will suffice.
   - See the Disrupting Earth's Orbit Activity for detailed instructions for this activity.
   - If the students are going to create animations, go over the basics of animation with them especially the part about frame rates. They will need to understand this concept to create a successful animation.
   - Pass out the Disrupting Earth's Orbit Activity sheets to the students.
   - Go over the project options.
   - Discuss whether it will be feasible to draw the planets to scale or why not. (See the Misconception discussed in Explore, Step 2.)
2. **Go over the basics of animation.**

   - Animation works by displaying a series of images which change slightly giving the illusion of movement.
   - Each image is called a frame. The frames can be drawn by hand, drawn or painted on a computer, or models can be photographed (often called "claymation").
   - The most basic way to animate is to create a flipbook. A flipbook is simply a stack of paper attached together. Each page is hand drawn with slight movement changes between each page. The animation is viewed by "flipping" through the pages using your thumb. The problem with this is that even elements that are not changing or moving from frame to frame need to be redrawn on each successive page.
   - Cel animation takes care of this problem. The part of the animation that moves is drawn on to clear "cels" which are placed over backgrounds. Elements that do not move or change only need to be created once saving time and energy.
   - Computer animation uses these same ideas and adds some features to make the process easier.
   - To create animations for this activity, the students will use cutouts of Earth and Jupiter against the Jupiter’s Orbits Diagram to create the animation (sort of a blend between cel animation and Claymation). They will need a digital camera and a program for taking a series of images and putting them into an animation.
   - There are several free programs that create animations in different formats including: animated GIF's (the standard animation format for web pages), QuickTime movies (Macintosh platform), or Avi movies (Windows platform). Search your favorite shareware or freeware site for “animation” and your desired format (GIF, QuickTime, or Avi) and you should be given several options. Try a few until you find one that will work for your students. Please note, more powerful animation programs will be able to do more, but will also require more effort to learn. The advantage to the free ones (in addition to their being free) is that the students have to focus on the basic principles of animation. This will better prepare them to use more powerful programs in the future.
   - One of the most significant factors in creating any animation is frame rate. This is the speed at which the frames are displayed. It is measured in frames per second. In general, the higher the frame rate (the more frames showing each second), the smoother the animation looks. Of course, the higher the frame rate, the more frames you need to create. In a flipbook, the frame rate is determined by how quickly the pages are flipped. In the animation programs, you choose the rate at which the frames are displayed. Standard video (on television etc.) shows at 29.5 frames per second (or fps). Movies shown in a theater tend to use 24 fps. Five frames per second tends to look a little choppy while ten frames per second can look almost smooth. The choice of frame rate will most likely depend on the length of the animation. A 5-second animation will require 25 frames at 5 fps and 50 frames at 10 fps.
     - The formula for frames is: \( f = s \times r \)
     - \( f \) = number of frames in the animation
     - \( s \) = number of seconds in the animation
     - \( r \) = the frame rate (in frames per second)
     - The \( \times \) sign indicates multiplication

3. **Encourage the students to think in terms of the time for their animation.**

   Not only will this help them to choose an appropriate frame rate, but also it will help them to make their changes from frame to frame more evenly. For example, if they know that they have 10 frames to move Jupiter from point A to point B, then they know that they need to move Jupiter one tenth of that distance from frame to frame in order to get even movement and to be sure Jupiter is at the right point at the right time/frame.

   **Note to Teacher:** The instructions for this activity are on the Disrupting Earth’s Orbit Activity sheet at the end of this lesson.
Evaluate (approximately 45 minutes)

1. Have students share their animations and explain the effects of the disruption on Earth, Earth’s temperature system, life on Earth and why.
   • Question: Which part of the Earth’s temperature system is being disrupted?
     • Answer: The orbital distance from the Sun.

   • Question: What effect does this have on Earth’s surface temperature?
     • Answer: It depends on the result:
       • If Earth were ejected from the Solar System, the temperature would grow very cold and water would freeze.
       • If Earth were sent into the Sun, it would burn up.
       • If Earth became a moon of Jupiter, it would be in the same highly elliptical orbit that Jupiter is in. Therefore, its temperature would not remain stable and would fluctuate between all water being frozen and boiling off into steam.
       • If Earth were pulled into Jupiter, it would be engulfed as a part of Jupiter.
       • If Earth reestablished an orbit with the Sun at a greater distance from the Sun, it would probably be outside of the Habitable Zone causing temperatures to fall and water to freeze.
       • If Earth’s orbit became highly elliptical, its temperature would not remain stable and would fluctuate between all water being frozen and boiling off into steam.

   • Question: So, in order for a planet like Earth to maintain a stable temperature that supports human life, what needs to happen?
     • Answer: A large object such as Jupiter must not be in a highly elliptical orbit in which it could disrupt the habitable planet’s orbit. There must be no large objects or the large object must orbit in a more circular orbit that is at a good distance from the habitable planet.

Note to Teacher: Scientists do not agree on whether a large planet such as Jupiter is necessary for life. Some scientists argue that Jupiter has protected life on Earth by attracting debris such as asteroids and comets that could have crashed into Earth destroying life. However, other scientists argue that although this is true of our system, other systems may not need a “vacuum cleaner” like Jupiter, because they may not have as many asteroids and comets. In fact, it is possible that if it weren’t for Jupiter, that our asteroid belt might have formed into another planet thus greatly reducing the number of asteroids in our Solar System. Therefore, in Astro-Venture, we only focus on the necessity for any large Jupiter-size planets to be in a circular orbit far from any habitable planets.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding.
Disrupting Earth’s Orbit Activity

If Jupiter's orbit were elliptical at 1 AU (the distance of Earth from the Sun), it would have the potential to disrupt Earth's orbit. There are some possible outcomes of that disruption. For the assigned possible outcomes you must:

1. Illustrate and explain how the disruption occurred (show how Jupiter could disrupt Earth's orbit).
2. Illustrate and explain what could happen to Earth (be sure to indicate that it is one of many possibilities).
3. Explain what happens to water on Earth.
4. Explain what happens to the Earth's ability to support human life.

Projects

Option A: Series of Illustrations
Create a series of 4 to 8 illustrations with captions that meet the above requirements. You should also include a separate write-up to cover requirements 3 and 4.

Option B: Animation
Create a short animation to meet the above requirements. You should include a separate write-up to cover the written explanation requirements.

Materials:
- Jupiter's Orbits Diagram
- Digital Camera
- Animation Program for the computer
- Cardboard (to build a frame to support the Jupiter's Orbits Diagram
- Cut out Jupiter and Earth
- Tape or weak glue (the kind used in post-it notes).

Procedure:
- Make cut-out of Jupiter and Earth
- Label Jupiter's Orbits Diagram. Be sure to include information about scale (i.e. which parts are to scale and which parts are not).
- Plan the Animation
  - Decide the length of the animation (5 to 10 seconds)
  - Decide the frame rate (5 frames per second or 10 frames per second)
  - Plan the movement of the planets
- Mount the Jupiter's Orbits Diagram onto the cardboard so that it can stand up on its own.
- Position the camera so that you can see the Jupiter's Orbits Diagram (and only that) in the viewfinder of the camera.
- Use the tape or weak glue to put the planets in their starting positions.
- Shoot a frame. (Take a picture.)
• Move the planets to their next positions. Shoot another frame.

• Repeat the process until all frames have been shot.

• Transfer the pictures to a folder or directory on a computer.

• Follow the instructions for bringing the pictures into the animation program and creating the animation.
  • Most programs will use one of two methods. Either each picture will need to be added to animation one by one, or the program will require you to open the first picture in the sequence and will then import the rest in order.
  • Set the frame rate to the one you decided upon.

Your project will be evaluated using the following rubric. Please note that some elements of the rubric may not apply to both illustrations and animations.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>The disruption and its effects on Earth, water, and human life are accurately, creatively and elegantly portrayed in the illustration and explained concisely and effectively in the captions. Elements on the illustration or in the animation are spaced appropriately and design elements (color, lines, shapes, and content illustrations) make it exceptionally clear and easy to understand. The animation flows consistently well.</td>
</tr>
<tr>
<td>3</td>
<td>The disruption and its effects on Earth, water, and human life are clearly and accurately portrayed in the illustration or animation and explained in the captions. Elements on the illustration or in the animation are spaced appropriately, and design elements (color, lines, shapes, and content illustrations) make it easy to read and understand. The animation flows well.</td>
</tr>
<tr>
<td>2</td>
<td>The disruption and its effects on Earth, water, and human life are not completely clear or completely accurate. Elements on the illustration or in the animation could be better spaced and design elements (color, lines, shapes, and content illustrations) make it a little difficult to read and understand. The animation is jerky and skips parts.</td>
</tr>
<tr>
<td>1</td>
<td>The disruption and its effects on Earth, water, and human life are unclear or inaccurate in the illustration, animation, or caption. Elements on the poster are either squashed together or large spaces are empty, and design elements (color, lines, shapes, and content illustrations) make the poster difficult to read. The animation shows little or no flowing movement.</td>
</tr>
</tbody>
</table>
Jupiter’s Orbit Diagram

Student Version
Please note:
The orbital distances are drawn to scale. However, the size of the Sun in proportion to the planet’s orbits is NOT to scale. The Sun would be 500 times smaller at this scale!
Jupiter and Earth cut-outs 1

In this example Jupiter and Earth are NOT proportional or to scale.
In this example Jupiter and Earth are PROPORTIONAL to each other but not to scale.
Jupiter Orbits Diagram to Scale
Starting on page 194, we have included a nine-page classroom-size diagram of the Sun, Earth's orbit, Jupiter's orbit and a hypothetical elliptical orbit for Jupiter. Once all nine pages are printed and taped together you will have a model that is to SCALE. Students will be able to see how small the Sun is in proportion to the orbits of Earth and Jupiter—quite an eye-opener!

To assemble the nine-page diagram, tape them in sequence in "landscape" orientation. See the picture below.

---

Build your own Solar System to scale!
Make a scale model of the Solar System and learn the REAL definition of "space."

http://www.exploratorium.edu/ronh/solar_system/

- Fill in the diameter of the Sun (in inches or millimeters) by which you want your model to be scaled.
- Click the "Calculate" button.

The proportional sizes of the planets will automatically fill in, along with a scaled orbit radius (in feet and inches or meters). Also provided are some other interesting scale comparisons at the bottom of the chart.
Jupiter's Orbit Diagram
Please note:
This diagram is drawn to SCALE!
Including the scaled size of how large the Sun would be in proportion to the planets' orbits.

In this example the Sun's diameter is only .02 inches (.5mm)! If Earth and Jupiter had been drawn in to scale, their diameter would on be .0001 inches and .002 inches respectively.
Astro Journal

Embraving on an Astronomy Astro-Venture!

By: __________________________

(your name)
## Astro Journal

<table>
<thead>
<tr>
<th>Scientific Question:</th>
<th>Name:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Data Collection: Record and display your data in a chart, table, picture or graph.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hypothesis/Prediction: What do you predict and why?</th>
<th></th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Materials: What materials will you use to investigate?</th>
<th>Results: Summarize what your data mean.</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Procedure: List the steps you will take to investigate.</th>
<th>Conclusions: Compare and contrast your hypothesis and results. How did testing your hypothesis/prediction change your original ideas?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Step 1:</td>
<td></td>
</tr>
<tr>
<td>Step 2:</td>
<td></td>
</tr>
<tr>
<td>Step 3:</td>
<td></td>
</tr>
<tr>
<td>Step 4:</td>
<td></td>
</tr>
<tr>
<td>Step 5:</td>
<td></td>
</tr>
</tbody>
</table>
### Scientific Inquiry Evaluation Rubric For Evaluating Astro Journal Entries

<table>
<thead>
<tr>
<th>Component</th>
<th>Expectations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hypothesis/Prediction</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Specific enough to be testable/observable and give a meaningful result</td>
</tr>
<tr>
<td></td>
<td>• Has basis in solid information or observations and a logical reasoning process</td>
</tr>
<tr>
<td>Materials, Procedures, and Data</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Complete</td>
</tr>
<tr>
<td></td>
<td>• Accurate and tied directly to hypothesis and scientific question</td>
</tr>
<tr>
<td>Results</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to Scientific Question and data</td>
</tr>
<tr>
<td></td>
<td>• Draws a reasonable conclusion from that data</td>
</tr>
<tr>
<td>Conclusions</td>
<td>• Clearly stated</td>
</tr>
<tr>
<td></td>
<td>• States how hypothesis/prediction was confirmed and/or altered</td>
</tr>
<tr>
<td></td>
<td>• Refers directly to findings, observations, and/or data to explain why thoughts were changed</td>
</tr>
</tbody>
</table>

**Scores:**

4: Expectations Exceeded  
3: Expectations Met  
2: Expectations Not Quite Met  
1: Expectations Not Met
Part 4:
Unit Conclusion and Evaluation
Lesson 13: Astronomy Mission Module Training

Students use an online, multimedia module to simulate the techniques that scientists might use to find a star system and planet that meet the astronomical conditions required for human habitability. Students then summarize their learning from this unit in a final project.

Main Lesson Concept: Scientists use methods such as spectroscopy, Doppler Shift, photometry and Kepler's Third Law to collect data from a star. They then interpret this data to determine if the star system has the astronomical conditions required for human habitability.

Scientific Question: What are the chances that there is a star system other than our own that has the astronomical conditions required for human habitability? Explain.

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will use scientific inquiry to describe the process scientists use to find a star system that has the astronomical conditions required for human habitability.</td>
<td>Addresses:</td>
</tr>
<tr>
<td>Students will compare and analyze data to find a star system that meets the astronomical conditions required for human habitability.</td>
<td>2061: 1B 6-8, #1</td>
</tr>
<tr>
<td></td>
<td>NSES: A 5-8 #1</td>
</tr>
<tr>
<td></td>
<td>NCTM: 5, 9</td>
</tr>
<tr>
<td></td>
<td>ISTE: 3, 5, 6</td>
</tr>
</tbody>
</table>

Assessment: Write-up in Astro Journal, printout of Astronomy Mission Newspaper Article.

Abstract of Lesson: Students predict the chances of finding another star system with the astronomical conditions required for human habituation. They engage in an online Astronomy Mission module in which they simulate the methods scientists might use to find a star system with these characteristics. They then describe this process.

Prerequisite Concepts:
- Humans need food, water and a moderate temperature in order to survive. (Lesson 1)
- The following characteristics allow Earth to remain habitable to humans:
  - A yellow star
  - Jupiter in a circular orbit beyond three astronomical units (AU)
  - An Earth-size planet of a mass that is between one-fourth and four times Earth’s mass
  - The orbit of the Earth-size planet is in the Habitable Zone. (Lesson 2)
  - Scientists categorize stars by their temperature and brightness or luminosity. (Lesson 9)
  - Stars in the middle of the main sequence on the HR diagram (yellow stars) are ideal for human life, as they burn at a moderate temperature that remains relatively stable over time. (Lesson 9)
  - The Habitable Zone is the distance from a star where liquid water can exist on a planet’s surface at all times. (Lesson 9)
  - The amount of atmosphere on a planet depends on the planet’s gravity, which is determined by the planet’s mass. (Lesson 11)
  - If Jupiter were in an elliptical orbit at 1 AU, it could cause a change in Earth’s orbit, which would have consequences for the planetary temperature system. (Lesson 12)

Major Concepts:
- Scientists define a scientific question for study, make a hypothesis based on this question, collect data to answer the question, report their results and draw conclusions.
- Scientists can use spectroscopy to locate yellow stars.
- Scientists can use Doppler Shift to detect Jupiter-size planets in an elliptical orbit.
- Scientists can use photometry to detect Earth-size planets.
- Scientists can use Kepler’s Third Law to determine if any Earth-size planets are orbiting in the Habitable Zone.
- Spectral data, graphs and measurements are the types of data that astrophysicists can collect using their instruments. This data is then interpreted for meaning.
Suggested Timeline (45-minute periods):
Day 1: Engage and Explore Part 1 Sections (35 minutes)
Day 2: Explore Part 2 Section
Day 3: Explain and Extend/Apply Sections
Day 4: Evaluate Section (25 minutes)

Materials and Equipment:
- A class set of Astro Journals Lesson 13: Astronomy Mission Module and Astrobiology Missions Activity *
  (Most of this is optional, as it will be completed online; however, you will need the Description section).
- Astronomy Mission Walkthrough (Optional)
- 1-30 computers with Internet browser, Internet connection and the Shockwave/Flash Player installed
- A printer connected to the computers
- Chart Paper
- "Y" cables (optional, used for student pairs)
- headphones

Preparation:
- Duplicate a class sets of Astro Journals.
- Download and install Shockwave/Flash Players on computers. Test these at http://astroventure.arc.nasa.gov by clicking "Astronomy Mission."
- Test Astrobiology Mission links to make sure sites are current. If they are not, research other sites using provided NASA resources.
- Prepare and post chart paper with major concept of the lesson and human survival needs.
- Gather headphones and "Y" cables
- Duplicate class set of Lesson 13: Astronomy Mission Module and Astrobiology Missions Activity.

Note To Teacher: A generic Astro Journal is included with the Instructional Materials. If you prefer, you can have students use the generic Astro Journal instead of the ones designed to go with each lesson. This might be especially useful for older students who are already familiar with the inquiry method.

Differentiation:
Accommodations
For students who may have special needs:
- Pair advanced students with students that may need more guidance.
- Encourage students to talk about what they are learning, as they go through the computer activity.

Advanced Extensions
Research and report on the methods used to find planetary systems outside of our Solar System.
- How were these planets detected?
- What are the characteristics of these systems?
- Do any of the planets detected outside of our star system meet the astronomical conditions required for human habitability? Explain.
1. **Review Part 3.**
   - **Question:** What have we learned are the necessary astronomical conditions for human habitability?
   - **Answer:** The following astronomical characteristics allow a planet to remain habitable to humans:
     - A yellow star.
     - No Jupiter-size planets or any Jupiter-size planets in a circular orbit beyond three astronomical units (AU).
     - An Earth-size planet of a mass that is between one-fourth and four times Earth’s mass.
     - The orbit of the Earth-size planet is in the Habitable Zone.
   - **Question:** Why do we need these astronomical conditions?
   - **Answer:** The temperature of a star and the orbital distance of a planet work together to maintain a moderate temperature on a planet so that water can be present in liquid form at all times. The mass of a planet determines how much of an atmosphere the planet has, which also contributes to maintaining a moderate temperature on the planet. No Jupiter-size planets or other large objects can interfere with the stability of this system.

2. **Introduce the purpose of the lesson.**
   - **Say:** Now that we know what astronomical conditions are needed for human habitability and why, we are now going to look at how scientists might go about finding such a system.

3. **Bridge to this lesson.**
   - **Question:** What methods do you think scientists might use to look for a star system with the characteristics we have listed?
   - **Answer:** (Accept all answers. Students may suggest that scientists could use telescopes to look at stars. Use this as an opportunity to assess students’ prior knowledge. Encourage students to discuss the kinds of information they think astrophysicists might be able to learn using a telescope. Ask them how they think scientists would determine a star’s type or how they would detect any planets around a star. Ask students if scientists have found any planets outside of our star system and what these planets are like.)

Note to Teacher: Over 70 planets have been found outside of our Solar System. Most of these are the size of Jupiter or larger. The smallest is about the size of Saturn. Thus far, scientists have used Doppler Shift to detect these planets. Doppler Shift is only effective in detecting large planets. The process of photometry described in Astronomy Mission used to detect Earth-size planets is a proposed method for future missions such as the Kepler Project. To learn more about this project, visit: http://www.kepler.arc.nasa.gov

   - **Say:** A telescope is one instrument that astrophysicists and astronomers use to detect the light of stars so that we can learn more about them.

   - **Question:** Are all telescopes the same?
   - **Answer:** There are many types of telescopes that can collect different kinds of radiation. The telescopes we usually think of collect visible light or the light people can see with their eyes. There are also telescopes that collect ultra-violet light, microwaves or other radiation that we can’t see.
• Question: Are telescopes the only instruments we can use to study stars?
  • Answer: No, there are other devices that scientists can attach to their telescopes to gather additional information. For example, scientists can attach a spectrometer to a telescope to determine the temperature of a star, or a photometer can be used to detect a change in a star's brightness. Often, astrophysicists collect many measurements and use math equations to find out other information about a star. Computers are also a very important tool that astrophysicists use.

• Say: As Astro-Venture Senior Astronomers, you will be learning about some of the tools and methods scientists use to study stars. As you complete the online Astro-Venture Astronomy Mission module, it is your mission to find a star system that has the astronomical conditions required for human habitation.

4. Present the Scientific Question for this lesson.
• What are the chances that there is another star system that meets the astronomical conditions required for human habitation? Why?
• Tell students that they will be completing the online Astronomy Mission module to search for a star system that meets the requirements necessary for human habitation.

1. Discuss students' predictions of what they believe are the chances that there is another star system that meets the astronomical conditions required for human habitation and why.

Note to Teacher: Students will be asked to enter their predictions and conclusions in the online module. If you complete the module as a whole class, you may want students to complete all sections of the Astro Journal: Lesson 13. This may also be useful if you want to reinforce the importance of data collection by having students write down the data, rather than simply letting the computer do it.

• Question: What do you think are the chances of finding another star system with the astronomical conditions required for human habitation?
  • Answer: (Accept all answers. Encourage students to give answers in a percentage format. You might have students vote on whether they think there is less than a 50% chance, a 50% chance, or more than a 50% chance of finding a star system with these conditions.)

• What is your reasoning for giving this answer?
  • Answer: (Answers may vary. Students who feel that it is less likely that a star system with these conditions could be found may explain that in our own Solar System, only 1 out of 9 planets formed with the necessary conditions. Another argument might be that with so many requirements, it seems unlikely that we might find a planet that can meet them all. Students who feel that it is more likely that a star system with these conditions could be found may explain that since there are billions of stars, there is a high probability that at least one of them meets the requirements.)

Note to Teacher: Scientists do not yet know the answer to this question. Drake’s Equation is one method that scientists have identified for trying to calculate this probability. However, at this time we still do not have an accurate estimate of many of the variables in this equation. Therefore, scientists do not agree on the level of this probability. Some scientists, like those who work for Searching for Extra-Terrestrial Intelligence (SETI), believe there is a high probability of finding signs of other intelligent life like humans on other planets. Other scientists, like Peter Ward author of the book Rare Earth, believe that there is a low probability of finding complex life. Astrobiologists, in general, do agree that there is a good chance of finding microbial life, which they believe might be found in our own Solar System.
2. Introduce students to the Astro-Venture Astronomy Mission module.
   - Tell students that now that they have completed their Astronomy Training, and understand what astronomical conditions are necessary for human survival and why, they will use Astro-Venture Academy instruments to search for a star system that has these astronomical conditions. They will need to eliminate star systems that don't meet the requirements until they find a system that has all of the necessary conditions.
   - Tell students that as they go through this module, they will be Astro-Venture Senior Astronomers and will be using the scientific inquiry process. They will also have help from several NASA scientists.
   - Before students begin the Astronomy Mission module, be sure to emphasize with them the importance of making up a password that includes the date and to write this down exactly as they enter it. This password will be required at the end to complete the module. A sample password for the date March, 5 might be: nasamarch5

   Note to Teacher: Passwords will be periodically deleted from the database, so it will be important for students to complete the module within two weeks of having begun the module. The purpose of the password is to call up the teams’ names and prediction at the end of the module for comparison with their conclusions. When students print out the final page with their predictions and conclusions, the names entered will let you know whose work it is. If students forgot their password or come back after their passwords were deleted, you may want to use a permanent password that we will keep in the database. This password is: av01astro This will allow students to complete the ending; however there will be no prediction entry or names on their final printable page.
   - Tell students that they will be asked to switch players for each step. If they are in pairs or small groups, they should switch control of the mouse for each step.

Note to Teacher: The module relies heavily on audio, so we suggest that you obtain headphones for each computer. If pairs of students will share a computer, we suggest using “Y-cables,” which allow you to plug two pairs of headphones into one computer.

Explore Part 2 - (approximately 45 minutes)

1. Have students engage in the Astronomy Mission module individually, in pairs, small groups or as a class.
   - Students should visit: http://astroventure.arc.nasa.gov and click “Astronomy Mission.”

   Notes to Teacher:
   - You will need the Shockwave/Flash Player plug-in, which can be downloaded and installed from: http://sdc.shockwave.com/shockwave/download
   - Also, you will want to have accessibility to a printer, so that students can print their Newspaper articles at the end of the module. These can be used for evaluation purposes.
   - If you want to take the whole class through the module using one computer, use the Astronomy Mission Walkthrough as a guide.
   - When this module was tested with students in grades 5-8, the average completion time was approximately 45 minutes. Most students should be able to complete the activity in a class period. However, if a student does not complete the module, it is possible to come to where they left off by either writing down the URL of the page they are on, or bookmarking the page and writing down the name of the bookmark. This is NOT possible in the Astronomy Training module, but is an enhancement added to the Astronomy Mission module.
   - The Astronomy Mission module scenario is fictional, and all stars are fabricated. At the time this was written, we had yet to find any star systems outside of our own with Earth-size planets. However, the methods used are all authentic astronomy methods, and the procedure is a viable procedure, that with advances in astronomical instruments, could be used to find a habitable star system.
1. Have students share their results and conclusions.
   - Question: Did you find a star system with the necessary astronomical conditions for human habitability?
   - Answer: One star system was found with the necessary astronomical conditions for human habitability.

   - Question: What conclusions can you draw from this experience?
   - Answer: (Answers may vary) There are probably many star systems that do not meet the requirements to sustain human life. However, because there are so many stars, there probably is at least one that does. However, because there are so many stars, it can take a long time to study each one to find stars that do meet the requirements.

   - Say: The Astronomy Mission activity is a hypothetical situation. Scientists in fact do not know the probability of finding a star system with the conditions necessary for human habitation. However, many scientists do believe that there is a good chance that there is microbial life on other planets, and there are many missions planned to look for Earth-size planets and signs of life on other planets.

2. Have students complete the Description section of their Astro Journals.

3. Extend/Apply (approximately 30 minutes)

   1. Have students complete the Astrobiology Missions section of their Astro Journals.
      - Students visit NASA Web sites to research current astrobiology missions in which Earth-size planets, conditions for life or life on other planets are being researched.

      - Have students use the scientific inquiry process as outlined in the Astrobiology Missions section of their Astro Journals to explain how these missions will be carried out.

      - New missions are being added all of the time, but a few missions that were planned at the time this lesson was written include:

        - The Kepler Mission: http://www.kepler.arc.nasa.gov

      - Other useful Web sites include:

        - NASA Astrobiology Institute: http://nai.arc.nasa.gov
        - NASA Ames Astrobiology (Visit the Missions page): http://astrobiology.arc.nasa.gov
        - NASA Origins Program: http://origins.jpl.nasa.gov (Visit the Missions page)
        - NASA SpaceLink: http://spacelink.nasa.gov (search Astrobiology)
        - NASA Quest: http://quest.nasa.gov

        (See Astrobiology Press Releases under “In the News,” or search the archives.)

        - Students might also visit Internet search engines, and enter key words such as, “extra-solar planets,” “astrobiology,” or “exobiology.”
Evaluate (approximately 25 minutes)

1. Have students share their descriptions of their own missions and other NASA missions using the scientific inquiry process to explain these missions.
   - **Question:** What was the process that you used to find a star system with the astronomical conditions necessary for human habitation?
   - **Answer:** We predicted what the chances were of finding such a star. We then used:
     - spectroscopy to find yellow stars;
     - Doppler Shift to eliminate any stars that had Jupiter-size planets in an elliptical orbit;
     - photometry to find Earth-size planets;
     - Kepler's Third law to determine if the Earth-size planets were orbiting in the Habitable Zone.
   - Finally, we recorded our results and drew conclusions about what our results mean.
   - **Question:** From this activity, what have you learned are the important parts of the scientific inquiry process?
   - **Answer:** It is important to have a good scientific question to explore. It is also important to make an educated guess about what you believe the answer to this question will be. Then it is important to collect data that will help to answer this question. Whether or not your prediction was correct is not important. Either way you learn something and can draw important conclusions.
   - **Question:** Does the process end with these conclusions?
   - **Answer:** No, often what we learn from one mission brings up new questions, which inspire new investigations.
   - **Question:** What new questions does this discovery raise?
   - **Answer:** (Answers may vary, but hopefully students will raise the question: Does this planet meet other requirements for human habitation?)

2. Bridge to the next lesson.
   - Discuss whether the planet located is definitely habitable.
   - **Question:** Is the planet we located definitely habitable to humans?
   - **Answer:** The planet meets the astronomical conditions; however, it may not meet other requirements. For example, we do not know if the planet has water, oxygen, food, and protection from radiation and poisonous gases.
   - **Question:** How might we find out if this planet meets other requirements for human habitability?
   - **Answer:** In order to find out if this planet meets other requirements for human habitability we would need to study the planet further.

3. Tell students that in the next lesson they will need to convince others at the Astro-Venture Academy that further exploration of their planet is worthwhile.

4. Collect Newspaper Articles and Astro Journals and evaluate them using the Scientific Inquiry Evaluation Rubric to make sure students are ready for the next lesson.
   In particular, assess students understanding of the scientific inquiry process.

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult, but it is a powerful tool for building understanding. For this lesson, the chart of what is needed and why those conditions are needed should also be posted.
Astro Journal Lesson 13:
Astronomy Mission Module

1. **Scientific Question:**
What are the chances that there is a star system other than our own that has the astronomical conditions required for human habitability?

2. **Hypothesis/Prediction:** What do you think are the chances that there is a star system other than our own that has the astronomical conditions required for human habitability? Explain.

3. **Materials:** What source will you use to gather data that will help answer this question?

4. **Data:** The following may be recorded online. However, you may use the following chart to record your observations. As you analyze each star, place an X next to “Habitable” or “Uninhabitable.” On each step, cross out the stars that were “Uninhabitable” in the previous step.

**Step 1: Spectroscopy**

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alison</th>
<th>Alpha</th>
<th>Amberix</th>
<th>Conrad</th>
<th>DJrex</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wilmo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Step 2: Doppler Shift**

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alison</th>
<th>Alpha</th>
<th>Amberix</th>
<th>Conrad</th>
<th>DJrex</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wilmo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Step 3: Photometry

Step 4: Kepler’s Third Law
Astrobiology Missions Activity

Visit NASA Web sites to find missions that are looking for Earth-size planets, conditions for life on other planets or signs of life on other planets. Describe these missions using the following guidelines.

- New missions are being added all of the time, but a few missions that were planned at the time this lesson was written include:
  - The Kepler Mission: http://www.kepler.arc.nasa.gov

- Other useful Web sites include:
  - NASA Astrobiology Institute: http://nai.arc.nasa.gov
  - NASA Ames Astrobiology (Visit the Missions page): http://astrobiology.arc.nasa.gov
  - NASA Origins Program: http://origins.jpl.nasa.gov (Visit the Missions page)
  - Planet Quest: http://planetquest.jpl.nasa.gov
  - NASA SpaceLink: http://spacelink.nasa.gov (search Astrobiology)
  - NASA Quest: http://quest.nasa.gov
    (See Astrobiology Press Releases under "In the News," or search the archives.)

Title of the mission: ____________________________

Web site address where information on this mission was found: ____________________________

Scientific question being studied by this mission (What are scientists trying to learn?): ____________________________

Scientific hypothesis (What do scientists think they will find on this mission?): ____________________________

Materials and instruments scientists will use to gather data: ____________________________

Methods and procedure scientists will use to gather data: ____________________________

If the mission is completed, report the results that were found. ____________________________

If the mission is completed, what conclusions did scientists draw? ____________________________
Astro-Venture: Astronomy Educator Guide

Part 4

Module Training

Final Project

Astronomy Mission Walkthrough

The following is an explanation of each section of Astronomy Mission. It offers suggestions for how you might take a whole class through the module, if you only have one computer with the ability to project. Audio is crucial to this module, so you will want to have a computer with speakers.

Introduction

• Students will be asked to enter a password from Astronomy training (av2002astro) or to answer the four questions from Training to ensure that they know the astronomical conditions required for humans.
• Astro Ferret will give an introduction to Astronomy Mission. Have students listen to this introduction. The arrow in the bottom left corner will allow you to replay each screen. The bottom right arrow allows you to advance to the next screen. Note to Teacher: When this module was tested with students in grades 5-8, the average completion time was approximately 35 minutes. You should be able to complete the activity in a class period. However, if you do not complete the module, it is possible to come to where you left off by either writing down the URL of the page you are on, or by bookmarking the page and writing down the name of the bookmark. This is NOT possible in the Astronomy Training module, but is an enhancement added to the Astronomy Mission module.
• On the prediction page, make up a password for the class that includes the date. Write down this password, as you will need it again at the end of the module.
• If students complete this module in pairs or small groups, we encourage each student to enter their first name. However, when completing this as a whole class, we suggest entering a name such as “Mrs. Jones’ class.” Note to Teacher: Passwords will be periodically deleted from the database, so it will be important for students to complete the module within two weeks of having begun the module. The purpose of the password is to call up the teams’ names and predictions at the end of the module for comparison with their conclusions. When students print out the final page with their predictions and conclusions, the names entered will let you know whose work it is.
• Ask students what they predict are the chances that there is another star system that meets the astronomical conditions for human survival and why. Enter a prediction that is agreeable to the class.
• Once the class has completed all fields, click “Enter.”
• Astro Ferret will explain the materials and procedure that students will use on their mission.

Step Animations

• There are four steps in the Astronomy Mission:
  1. Using Spectroscopy to Determine a Star’s Type
  2. Using Doppler Shift to Detect Jupiter-Size Planet’s in an Elliptical Orbit
  3. Using Photometry to Detect Earth-Size Planets
  4. Using Kepler’s Third Law to Determine if Earth-Size Planets are in the Habitable Zone

Note to Teacher: The concepts presented in Astronomy Mission are simplified for this grade level and are largely supplied as background information. Although students are shown how the data is derived and what it means, students in this grade range are not expected to understand the complexities of how these data collection methods work. The activity requires them to compare data and to draw conclusions about what the data mean, which students have been able to do very successfully in the user testing we conducted.

• Each step begins with an animation in which a NASA expert and Astro explain the scientific technique featured in each step. They show how scientists use this technique to gather data, what this data looks like, what it means and how scientists interpret this data.
• To begin each step, Astro will introduce the NASA expert.
The expert and Astro will go through a sequence of animations that will show how the data is derived and what it means. When an expert asks Astro a question, you may want to pose the same question to the class to assess their understanding of the concepts.

"Link to Script" will bring up a window with the full script of all dialogue spoken in each step.

"Tech Notes" will bring up a window with a summary of the main concepts in each step.

"Career Fact Sheet" will bring up a printable PDF file with the career fact sheet of the specialist for that step.

Step Activities

Following the animation, students engage in an interactive activity in which they apply the concepts they have just learned. You may wish to have students take turns coming up to the computer to analyze each star system.

- Click a star that has a teal circle around it.
- The Star Data shows the data collected from that star.
- The Reference Chart shows the different data types possible and what is meant by each of the data. Click the arrows to see each possible data type.
- The questions ask students to interpret the data and decide whether the star system is habitable or not. Click the circle next to the answer you wish to select.
- Click "Notes" to see the Tech Notes summary of the concepts for each step.
- Click "Hint #1" for help on how to decide what the data mean.
- Click "Hint #2" for help on deciding whether the star system would be habitable or not.
- Once students answer the questions correctly, the star will be checked off as completed and will be recorded as “habitable” or “uninhabitable” in the Astro Table.
- When students correctly analyze all stars, they will be congratulated and advanced to the next step.
- For steps 2, 3 and 4, students will be alerted that the stars eliminated from the previous step will be removed from the screen. Subsequently, there will be fewer stars to analyze for each additional step.

The stars that are eliminated at each step are as follows:

Step 1: Spectroscopy

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alisan</th>
<th>Alphal</th>
<th>Amberix</th>
<th>Conrad8</th>
<th>DJRes</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wiomo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>
Step 2: Doppler Shift

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alison</th>
<th>AlphaL</th>
<th>Amberix</th>
<th>Conrad8</th>
<th>DJRex</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wiomo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Step 3: Photometry

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alison</th>
<th>AlphaL</th>
<th>Amberix</th>
<th>Conrad8</th>
<th>DJRex</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wiomo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Step 4: Kepler’s Third Law

<table>
<thead>
<tr>
<th>Astro Table</th>
<th>Alison</th>
<th>AlphaL</th>
<th>Amberix</th>
<th>Conrad8</th>
<th>DJRex</th>
<th>Dozeria</th>
<th>GRTIO</th>
<th>4X-Tina</th>
<th>R-Sim2</th>
<th>8Terion</th>
<th>Marchel</th>
<th>Wiomo4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Habitable</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uninhabitable</td>
<td>X</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Conclusion

- After successfully completing the last step, Astro will ask students to enter their password that they chose at the beginning. This must be typed exactly as it was originally entered. Click “Enter.”

  Note to Teacher: If students forgot their password or come back after their password was deleted, you may want to use a permanent password that we will keep in the database. This password is: av01astro. This will allow students to complete the ending; however, there will be no prediction entry or names on their final printable page.

- Students will see their prediction that they entered at the beginning. They will be asked to enter their conclusion and to name their planet. Click “Enter.”

- Students will see a newspaper article written about them that will include their names, the name of their planet, their original prediction and final conclusions. The article summarizes the process the students went through to locate a star system with the astronomical conditions required for human habitability. Read this article with the class.

- Print out a copy of this article by going to the “File” menu of your browser and selecting “Print.”

- Discuss whether the planet located is definitely habitable.
  - Question: Is the planet we found definitely habitable to humans?
  - Answer: The planet meets the astronomical conditions; however, it may not meet other requirements. For example, we do not know if the planet has water, oxygen, food, and protection from radiation and poisonous gases.

  - Question: How might we find out if this planet meets other requirements for human habitability?
  - Answer: We would need to study the planet further.

- Click the trading card link to bring up the printable trading cards of the experts in this module.

- Click the arrow to go to the final page, which explains that further study of this planet will need to be conducted in additional Astro-Venture modules.
Students use an online, multimedia module to simulate the techniques that scientists might use to find a star system and planet that meet the astronomical conditions required for human habitability. Students then summarize their learning from this unit in a final project.

**Main Lesson Concept:** The astronomical requirements for habitability are not sufficient for sustaining human life on a planet. Additional requirements must be met to sustain human life on a planet.

**Scientific Question:** What other requirements must a planet meet to be habitable to humans and how might a scientist determine if a planet meets these requirements?

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will write a proposal to convince the &quot;World Science Foundation&quot; that the star and planet they found is worthy of further study and exploration. They will include a description of how the planet meets astronomical requirements for human habitability, additional requirements that must be met, the benefits of conducting this study and the type of further study they would recommend for determining if the planet meets these additional requirements.</td>
<td>Addresses: NSES: A 5-8 #1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Assessment</th>
<th>Abstract of Lesson</th>
</tr>
</thead>
<tbody>
<tr>
<td>Write-up of Proposal.</td>
<td>Students discuss what they know about the astronomical conditions of the planets they have found and what they still need to know in order to determine if it is habitable to humans. They research possible methods for answering these questions and write a proposal on how and why their planet should be further researched.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Prerequisite Concepts</th>
<th>Major Concepts</th>
</tr>
</thead>
</table>
| • Humans need water, oxygen, food, gravity, a moderate temperature and low levels of poisonous gases and high levels of radiation to survive. (Lesson 1)  
• The following astronomical characteristics address some of these requirements that help to make Earth habitable to humans:  
  • A yellow star  
  • Jupiter in a circular orbit beyond three astronomical units (AU).  
  • An Earth-size planet of a mass that is between one-fourth and four times Earth’s mass  
  • The orbit of the Earth-size planet is in the Habitable Zone. (Lesson 2) | • From the astronomical requirements met by the planet located in Lesson 13, we can draw the following conclusions:  
  • The planet is likely to have enough gravity for our biological systems to operate normally  
  • The planet is likely to have a moderate temperature necessary for human survival and to maintain water in a liquid state.  
  However, we do not know if the planet has food, oxygen, water, low levels of poisonous gases and protection from high levels of radiation. We do not even know if the planet has an atmosphere and the right amount of gases in the atmosphere to maintain a moderate temperature.  
  • Further study of the planet, using powerful, space-based telescopes, interferometry and spectroscopy are necessary. Sending probes to the planet would give us more precise data.  
  • Study of habitable planets can help us better understand Earth and can help us to conclude whether life on Earth is unique. |
Suggested Timeline (45-minute periods):
Day 1: Engage and Explore
Day 2: Explain and Extend/Apply Sections
Day 3: Evaluate Section (1/2 of class presentations)
Day 4: Evaluate Section (1/2 of class presentations)

Materials and Equipment:
• A class set of Astro-Venture Proposal Guidelines
• Human Needs Chart from Lesson 1
• 1-30 computers with Internet browser and Internet connection
• Chart Paper

Preparation:
• Duplicate class sets of Astro-Venture Proposal Guidelines.
• Test Astrobiology Mission links to make sure sites are current. If they are not, research other sites using provided NASA resources.
• Prepare chart paper with major concept of the lesson to post at the end of the lesson.
• Duplicate and post the Human Needs Chart: Lesson 1

Differentiation:

Accommodations
For students who may have special needs:
• Pair more advanced students with students that may need more guidance.
• Evaluate students on oral presentations of proposals.

Advanced Extensions
Research and report on current methods used to power a probe to another planet or location in our Solar System.
• How fast do these probes travel?
• How is their direction controlled?
• How is their data collection controlled?
• What would be the advantages and disadvantages of using these techniques to send a probe outside of our Solar System?
1. **Review requirements for human survival from Lesson 1 and overall Astro-Venture goal.**
   - Question: What is the overall goal we've been working on at the Astro-Venture Academy?
   - Answer: At the Astro-Venture Academy, we are studying and trying to find another planet that would be habitable to humans.

   - Question: What are the basic human survival needs that this planet must meet?
   - Answer: (Refer students to the posted chart of human needs from Lesson 1.) We need water, oxygen, food, gravity, a moderate temperature and low levels of poisonous gases and protection from high levels of radiation to survive.

2. **Review Lesson 13 and bridge to Lesson 14.**
   - Question: In your Astronomy Mission you located a star system and planet. What characteristics does this star system have?
   - Answer: The star system has a yellow star, a Jupiter-size planet in a circular orbit beyond three AU, and an Earth-size planet orbiting in the Habitable Zone.

   - Question: What do these characteristics tell us about the Earth-size planet in terms of its ability to support human life?
   - Answer: The star type, planet size and orbital distance tell us that the planet is likely to have a moderate temperature which would allow the planet to maintain water in a liquid state and would allow humans to maintain a moderate body temperature. The planet size also means that the planet is likely to have sufficient gravity for human biological systems to function normally. The orbit of the Jupiter-size planet means that the Earth-size planet is not likely to be disturbed by the larger planet.

   - Question: Is this planet habitable to humans?
   - Answer: We do not have enough information to know if the planet is habitable to humans.

   - Question: What additional questions do you have about this planet that you would need answered in order to decide if it is habitable or not?
   - Answer: (Accept all answers and record them on the board. Have students connect questions to the list of human needs, and ensure that all needs are addressed.) Questions may include:
     - Does the planet have liquid water?
     - Does the planet have an atmosphere?
     - Does the planet's atmosphere include enough oxygen?
     - Does the planet's atmosphere include the right amount of Greenhouse gases (or gases that will trap the right amount of heat)?
     - Does the planet have an average global temperature below 50º Celsius?
     - Does the planet have food or the conditions necessary for growing food?
     - Does the planet have a low level of poisonous gases that won't kill humans?
     - Does the planet have protection from high levels of radiation coming from the star or from cosmic rays?
MISCONCEPTION: Students may believe that because the planet has the astronomical requirements, that it has the right atmosphere, moderate temperature and liquid water. It is important to help them realize that these conclusions cannot be made at this time. We have no evidence that the planet has water, atmosphere of any kind nor the right temperature. To bring out these misconceptions, ask students the following questions:

- Question: Does the planet have liquid water? How do you know?
- Question: Does the planet have an atmosphere? How do you know?
- Question: Does the planet have a moderate temperature? How do you know?

To further challenge these misconceptions, ask students to describe various possible scenarios for the planet they found. These might include:

- A planet with a large quantity of Greenhouse gases that trap heat and cause the surface to be hot enough to melt lead.
- A planet with no atmosphere such that its temperature would vary between very hot when facing the star and very cold when facing away from the star.
- A planet with the right temperature but no liquid water present.
- A planet that has liquid water, the right amount and type of atmosphere and the right temperature.
- Question: How many of you think that it would be worthwhile to do some further study of this planet? Why?
  Answer: (Accept all reasonable answers.)

3. Introduce the purpose of the lesson and the Scientific Question.

- Say: Scientists often make discoveries that help to answer one question, but those discoveries bring up more questions. Science is a never-ending exploration and search for answers. However, there is a limit in time and money that determines what research actually happens. Scientists have to convince organizations that have money that their research is worth being funded. Now that you have found a planet that meets some of the conditions required for human habitation, you must convince the World Science Foundation that your planet is worthy of further study. The Scientific Question that you will be addressing in your proposal to this organization are:

- What other requirements must a planet meet to be habitable to humans, and how might a scientist determine if a planet meets these habitability requirements?

Your ability to continue your research at the Astro-Venture Academy will depend on the acceptance of your proposal by the World Science Foundation.
1. Have students explore methods that NASA and other scientists are using to study extra-solar planets.
   • Have students visit the following Web sites to understand the methods used in the study of extra-solar planets and to determine what kind of information could be learned about extra-solar planets using the described methods. Students should note methods that they think would help to answer the questions they have listed.
     • Terrestrial Planet Finder: http://tpf.jpl.nasa.gov
     • NASA Astrobiology Institute: http://nai.arc.nasa.gov
     • NASA Ames Astrobiology: http://astrobiology.arc.nasa.gov (Visit the Missions page.)
     • NASA Origins Program: http://origins.jpl.nasa.gov (Visit the Missions page.)
     • The Kepler Mission: http://www.kepler.arc.nasa.gov
     • Next Generation Space Telescope: http://ngst.gsfc.nasa.gov
     • NASA SpaceLink: http://spacelink.nasa.gov (search Astrobiology)
     • NASA Quest: http://quest.nasa.gov (See Astrobiology Press Releases under “In the News,” or search the archives.)

     • Students might also visit Internet search engines, and enter key words such as, “interferometry “spectroscopy,” or “astrobiology.”

1. Explain (approximately 15 minutes)

   1. Have students share their results and conclusions in small groups. Have them share methods that could help to answer each listed question. Possible answers might include the following:

      Questions
      • Does the planet have liquid water?
      • Does the planet have an atmosphere?
      • Does the planet’s atmosphere include enough oxygen?
      • Does the planet’s atmosphere include the right amount of Greenhouse gases (or gases that will trap the right amount of heat)?
      • Does the planet have a low level of poisonous gases that won’t kill humans?
      • Does the planet have protection from high levels of radiation coming from the star or from cosmic rays?

      Possible Methods to Answer
      A combination of the following methods would help to answer these questions:
      • Spectroscopy to obtain the absorption spectrum of a planet and determine the atmospheric composition. (Signs of water vapor in this spectrum would be evidence that the planet may have liquid water.)
      • These instruments would need to be on a telescope above the Earth’s atmosphere. Alternatively, a probe with these instruments could be sent closer to the planet.
Questions
- Does the planet have an average global temperature above 0º and below 50º Celsius?
- Does the planet have food or the conditions for growing food?

Possible Methods to Answer
- Once we know the atmospheric composition, star type and planetary distance we will be able to do calculations and draw conclusions about the temperature range of the planet. A precise measurement may require that a probe be sent to the planet.
- A very high resolution spectroscope to obtain an even more detailed absorption spectrum of a planet can be used to look for presence of chemicals that we do not expect to find unless biological activity is pumping it into the atmosphere. Chemicals like ozone and free oxygen cannot exist without being replenished by some biological process. Thus, if we detect these chemicals, it is a good indicator of life. Methane is also another indicator of life.
- Again to be absolutely sure that plants or animals are present or could survive, a probe would probably need to be sent to the planet.

Question: In general, what can you conclude will be necessary for further research?
Answer: We can conclude that, in order to do further research, we will need very powerful telescopes that are above our atmosphere. To really be sure, we may need to send a probe closer to the planet.

Note to Teacher: Currently, we have not sent a probe outside of our Solar System. The technology and time that is required for such a mission would be considerable. Although no missions are currently planned or considered feasible for such a mission in the near future, it may be possible in the distant future. Similarly, students may suggest that scientists need to visit the planet. Discuss the advantages and disadvantages of sending people to another planet outside of our Solar System. The advantages might include that humans can gather more precise data, more quickly and with fewer mistakes. The disadvantages might include the risk of human life and added cost and constraints of sending a spacecraft that must sustain human life and return it to Earth. It should be noted that with current technology, the time it would take a probe to reach the nearest star would exceed a human’s life span.

Extend/Apply (approximately 30 minutes)
1. Have students write their proposals to the World Science Foundation using the Astro-Venture Proposal Guidelines.
1. Have students present their proposals to the “World Science Foundation proposal committee.”
   • Give students five minutes to verbally present their argument to the class. Have the class ask questions about each students’ proposal to help determine which proposals they think are most worthy of funding. Some of the important conclusions that students should arrive at and discuss include:
     • We can conclude that the planets we have found are likely to have enough gravity for our biological systems to operate normally and to have a moderate temperature necessary for human survival and to maintain water in a liquid state. However, we do not know if the planet has food, oxygen, water, low levels of poisonous gases and protection from high levels of radiation. We do not even know if the planet has an atmosphere and the right amount of gases in the atmosphere to maintain a moderate temperature.
     • Further study of the planet, using powerful, space-based telescopes, interferometry and spectroscopy or probes to the planet are necessary.
     • Study of habitable planets can help us better understand Earth and can help us to conclude whether life on Earth is unique.
     • After students have presented their proposals, have the class vote on the proposal they would fund and why. Their reasons should include evidence that the proposal will result in worthwhile research and that the methods proposed are appropriate to the mission.

2. Discuss students’ conclusions and have students summarize their learning of this unit.
   • Question: In completing your Astronomy Training and Mission, what important concepts did you learn about habitable planets?
   • Answer: (Answers may vary. Record answers on the board. Help students to identify the following key concepts.)
     • Humans need water, oxygen, food, gravity, a moderate temperature, low levels of poisonous gases and protection from high levels of radiation to survive.
     • Liquid water is necessary for human survival, and the right temperature is a very important condition for maintaining liquid water on the surface of a planet.
     • Star type, planet mass and a planet's distance from a planet all work together to determine the surface temperature of a planet.
     • If the astronomical requirements of a planet and star system are met, this does not necessarily mean the planet is habitable to humans.

3. Bridge to the next unit.
   • Say: Congratulations on your successful Astronomy research at the Astro-Venture Academy. You have really helped to contribute to our understanding of habitable planets. If your proposals are accepted, you will be trained in other requirements for human habitation in the areas of: Geology, Atmospheric Sciences and Biology and you will engage in a mission to conduct further study of your planet to see if it meets these requirements. Good luck!

Note to Teacher: After each lesson, consider posting the main concept of the lesson some place in your classroom. As you move through the unit, you and the students can refer to the ‘conceptual flow’ and reflect on the progression of the learning. This may be logistically difficult; but it is a powerful tool for building understanding. For this lesson, the chart of what is needed and why should also be posted.
Astro-Venture Proposal Guidelines

You have located another planet and star system that has some of the conditions required for human habitability. In order to determine if it meets all of the requirements for human habitability, you will need to conduct further research. On a separate sheet of paper, write a proposal to the World Science Foundation, and convince the foundation that the star and planet you found is worthy of further study and exploration. Include the following:

- A description of the planet and star system you have found and what evidence you have that it meets the astronomical conditions required for human habitability
- Why these astronomical conditions are important for human habitability
- A description of additional requirements that must be met for the planet to be habitable to humans
- Possible methods that could be used to determine if the planet meets these additional requirements
- An explanation of what the benefits would be to conducting further research of this planet

Your concept map will be evaluated using the following rubric.

<table>
<thead>
<tr>
<th>Score</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Proposal clearly and accurately explains requirements for human habitability and provides accurate conclusions about the planet found. Proposal has all required parts and uses examples and reasoning to create an exceptionally powerful and detailed persuasive argument.</td>
</tr>
<tr>
<td>3</td>
<td>Proposal clearly and accurately explains requirements for human habitability and provides accurate conclusions about the planet found. Proposal has all required parts, makes specific references to examples, and uses good reasoning in explanations.</td>
</tr>
<tr>
<td>2</td>
<td>Proposal is not completely clear or accurate in explaining requirements for human habitability and accurate conclusions were not drawn about the planet found. Proposal has most required parts, makes some specific references to examples, and uses some good reasoning in explanations.</td>
</tr>
<tr>
<td>1</td>
<td>Proposal is not clear or accurate in explaining requirements for human habitability and accurate conclusions were not drawn about the planet found. Proposal is missing several parts, makes few specific references to examples, and uses little or no good reasoning.</td>
</tr>
</tbody>
</table>
Glossary

- **aerodynamics.** The way that air moves around objects.
- **aerospace.** Having to do with the Earth's atmosphere and space beyond Earth.
- **algebra.** A type of math that uses letters as symbols to represent numbers.
- **analysis.** The examination of something in detail by studying its parts.
- **aquatic.** Living or growing in water.
- **associate's degree.** A degree usually earned from a community college, junior college or vocational school after completion of two years of full-time study. This degree generally is equal to the first two years of study toward a bachelor's degree.
- **asteroid.** A rocky, metallic object that orbits a star.
- **Astro Journal.** In Astro-Venture, your Astro Journal is where you record your observations and the scientific process.
- **astro.** A prefix, which means star or space.
- **astrobiologist.** A person who studies life on Earth and the possibilities for life in the universe.
- **astrobiology.** The study of life in the universe.
- **astronomer.** A person who studies the universe beyond Earth.
- **astronomical unit (AU).** The average distance from Earth to the Sun, which is equal to 149,598,770 km or 93,000,000 miles.
- **astronomy.** The study of space beyond Earth.
- **astrophysics.** The science of the stars, objects related to stars and the forces that determine how they interact.
- **astrophysicist.** A person who studies the science of the stars, objects related to stars and the forces that determine how they interact.
- **atmosphere.** The air. The blanket of gases that surrounds some planets and moons.
- **atmospheric chemist.** A person who studies what the atmosphere is made of and studies chemical reactions that change what it is made of.
- **atom.** The tiniest particle of an element that has the same chemical properties of the element. The building blocks of all matter.
- **average.** Medium-sized. In the middle.
- **B.A.** (bachelor of art) A university or college degree earned after completion of at least four years of study.
- **B.S.** (bachelor of science) A university or college degree earned after completion of at least four years of study.
- **bachelor's degree.** A university or college degree earned after completion of at least four years of full-time study following high school. A B.S. stands for a bachelor of science. A B.A. stands for a bachelor of arts.
bacteria. A form of life that has only one cell and can be seen only with a microscope.

bio. A prefix that means life. In Astro-Venture, bio is short for biography, which tells you more about a person's life or background.

biochemistry. The study of matter that makes up living things, what the matter is made of, how it's structured and its features.

biology. The study of life.

biotechnology. The use of living things to create new products such as medicines or new techniques such as waste recycling.

black hole. An area of space around an object where gravity is so strong that even light cannot escape from the area.

blue star. A hot, bright, massive star that has a surface temperature between 20,000°-60,000° Kelvin.

boiling point. The temperature at which a liquid becomes a gas.

bond. (chemical) The force between atoms in a molecule.

botany. The study of plants.

calculus. A type of math that uses special kinds of symbols.

capacity. The largest amount that something can hold.

carbon dioxide. A colorless gas that can absorb heat in the atmosphere. Plants use carbon dioxide to make their food and animals exhale it when they breathe.

career. The order of events that occur in a person's work, over time.

cause. Something that produces an effect or result. To produce an effect or result.

Celsius. A scale that measures temperature where water boils at 100°C and freezes at 0°C. Between the boiling and freezing points, the scale is divided into 100 parts. People in most countries use Celsius. It is named after Anders Celsius.

center of mass. The balancing point between two masses.

ceramic. Hard, breakable, heat-resistant material made by heating clay at a very high temperature.

chemical. Having to do with the study of matter, what it's made of, how it's structured and its features.

chemical change. (chemical reaction) When molecules interact to form new molecules.

chemist. A person who studies chemistry.

chemistry. The study of matter, what it's made of, how it's structured and its features.

chlorofluorocarbons. (CFCs) Human-made substances made up of chlorine, fluorine and carbon atoms bound together, which break up and react with oxygen atoms in the upper atmosphere, causing ozone depletion.

college. A school where bachelor's degrees can be earned following high school.
combustion. A rapid chemical change that occurs when heat is produced faster than it can dissipate. The process of burning.

comet. A ball of ice and rock that orbits a star.

community college/junior college. A school that offers a two-year degree or certificate that is generally equal to the first two years of a four-year college.

composition. The parts that form or make up a whole.

computer electronics. The study of computer devices and systems and how they work.

Conservation of Matter. During chemical change, the number of atoms does not change. Matter is neither created, nor destroyed.

database. A collection of data that is organized in a way so that it is quick and easy to find.

demo. A demonstration. In Astro-Venture, a demo demonstrates how to use the module.

density. The amount of matter in a certain unit of volume or space.

DNA. (Deoxyribo Nucleic Acid) A long, complex molecule that contains the codes that control your cells' activities, the chemicals that make up your body and heredity.

document. The highest degree awarded by a university earned after completion of at least five years of study beyond a bachelor's degree. A Ph.D. is a doctorate of philosophy.

Doppler shift. The change in wavelength as a source of light or sound moves toward or away from you or as you move toward or away from a source of light or sound.

electrical engineering. The scientific technology of electricity for use in designing and developing equipment that produces power and controls machines.

electronics. The study of devices and systems that are powered by using electricity.

element. A substance that cannot be broken down into other substances. Oxygen, gold and hydrogen are 3 of the 115 elements.

elliptical orbit. An orbit that is more oval than circular.

engineer. A person who designs, constructs or builds. To design, construct or build.

engineering. The use of math and science to design and build structures, equipment and systems.

evaporate. To change from a liquid to a gas.

Europa. One of Jupiter's 16 moons. Study of Europa shows that it is composed of liquid-water ocean covered by an ice crust. Because it has this liquid ocean, scientists hope to find life there.

Fahrenheit. A scale that measures temperature where water boils at 212°F and freezes at 32°F. In the United States, we use both Fahrenheit and Celsius, but most people are most familiar with Fahrenheit. It was developed by Gabriel Daniel Fahrenheit.

fieldwork. Observations and work done in an actual work environment to gain real-life experience and knowledge.
flammable. Easily set on fire.

fluid dynamics. The study of liquids and how they move.

fluid mechanics. The study of the effect of forces on liquids.

freezing point. The temperature at which a liquid becomes a solid.

galaxy. A large group of stars that are held together by gravity.

gas. A state of matter that has no definite shape or volume. In a gas, the molecules are so loose, they can spread apart or can squeeze together, depending on the container they are in.

genetics. The study of genes and how they transmit features from parents to their children.

geologist. A person who studies Earth's origin, history and structure.

geology. The study of Earth's origin, history and structure.

geometry. A type of math that involves the measurement and features of shapes, points, lines, angles, surfaces and solids.

global effect. The effect on the whole Earth that occurs as a result of some change.

graphics. Information that is represented with images or pictures.

gravity. A force of attraction that exists between objects. The greater the mass and diameter of an object, the greater its gravitational pull.

greenhouse effect. Some gases, such as carbon dioxide and water vapor, absorb heat energy and hold it in the atmosphere raising the surface temperature of a planet.

habitable. Fit to live in.

Habitable Zone (HZ). The range of distances from a star where liquid water can exist on a planet's surface.

hardware. Computers and the equipment used with computers such as monitors, printers and disk drives.

H-R Diagram. A diagram created by two scientists, Ejnar Hertzsprung and Henry Norris Russell, to show how the brightness and temperature of stars are related.

human factors engineering. The use of psychology and other areas of science to develop systems that people use in a way that makes the system easy, safe and useful.

hypothermia. An abnormally low body temperature.

Ice Age. A long, cold period when a large part of a planet is covered with glaciers.

inert. An element or substance that does not easily react or interact with other elements or substances.

junior college. A school that offers a two-year degree or certificate that is generally equal to the first two years of a four-year college.
Kelvin. A scale that many scientists use to measure temperature. Kelvin degrees are the same as Celsius degrees, but the scale is adjusted so that zero represents absolute zero, which is the temperature at which all particles (electrons, atoms, molecules, etc.) have minimal motion. Water boils at 373º Kelvin and freezes at 273º Kelvin. The Sun is about 5,000-6,000º Kelvin. This scale is named after the nineteenth-century British scientist Lord Kelvin.

laboratory. A building used for scientific research.

liquid. A state of matter that has a definite volume but no definite shape. In a liquid, the bonds of molecules are looser than in solids so that the molecules can slide past each other.

luminosity. The amount of power or "wattage" put out by a star. How bright a star appears to us depends on its luminosity and its distance.

M.A. (master of art) A university degree earned after completion of at least one year of study beyond a bachelor’s degree.

M.S. (master of science) A university degree earned after completion of at least one year of study beyond a bachelor’s degree.

main-sequence stars. Stars ranging from hot blue to cool red dwarfs. The most common type of star. They are not giants, supergiants, white dwarfs or red dwarfs.

mass. The amount of matter in an object.

master’s degree. A university degree earned after completion of one to two years of study beyond a bachelor’s degree. An M.S. stands for a master of science degree. An M.A. is a master of arts degree.

matter. Anything that has mass and volume. Anything that takes up space.

mechanical engineering. The use of math and science to design and build structures, equipment and systems that produce heat or power.

melting point. The temperature at which a substance changes from a solid to a liquid.

metal. A group of elements that is shiny, bendable and conducts heat and electricity.

meteoroid. Small rocky objects that orbit a star.

meteorology. The study of the conditions in the atmosphere, especially weather.

microbe. A living thing that is so small, it can be seen only with a microscope. Bacteria and viruses are microbes.

microbiology. The study of microbes.

microscope. An instrument that uses lenses to make small objects appear large.


moon. A natural object that orbits a larger object, usually a planet.

navigate. To control the path or route of a ship, aircraft or spacecraft.

Nitrogen Cycle. The continuous movement of nitrogen from the atmosphere through bacteria, into the soil, to plants, to animals and its return to the air.
nebula. A huge cloud of gas and dust in space from which stars are born.

nervous system. A system in animals that controls the body functions and senses. In humans it includes the brain, spinal cord and nerves.

network. A number of computers connected together so that information can be sent between them.

neutron star. The remains of a supernova that become an extremely dense, tightly packed star.

nitrogen. A colorless, tasteless, odorless gas that makes up 78 percent of the atmosphere and is a necessary part of all living tissues.

observation. The act of watching carefully.

observatory. A building designed for making observations of stars or other objects in space.

occupation. The activity that a person does as their regular work. A job.

orbit. The path of an object around another object, caused by gravity. To move around another object.

oxidation. A chemical change in which a substance combines with oxygen.

oxygen. A colorless, odorless gas that is released by plants into the air, is essential to animals for breathing, and is highly flammable.

ozone. A gas made of three oxygen atoms bonded together. When ozone is located high in the atmosphere, it protects life from harmful ultraviolet radiation but can be harmful to life at Earth's surface.

ozone depletion. When ozone loss is greater than ozone creation.

ozone layer. The layer of gas in the stratosphere that protects the Earth from harmful ultraviolet rays.

paleontology. The study of fossils.

period of revolution. (period) The amount of time it takes the planet to orbit its star. Earth's period is 365 1/4 days or one year.

Ph.D. (doctorate of philosophy) The highest degree awarded by a university, earned after completion of at least nine years of college study following high school. This includes four years to earn a bachelor's degree and five to seven years to earn a Ph.D.

photometer. An instrument that measures the intensity of light.

photometry. The measurement of the intensity of light.

photosynthesis. The process by which plants convert sunlight and carbon dioxide to oxygen and sugar.

physical science. Any of the sciences, such as chemistry, physics, astronomy and geology that investigate the features of energy and nonliving matter.

physics. The study of matter and energy and how they work together.

physiology. An area of biology that studies the major functions of plants and animals such as growth, reproduction, photosynthesis, respiration and movement.
planet. A body that orbits a star and does not give off its own light. A planet is generally much smaller than a star and can be made of solid, liquid, and/or gas.

planetarium. A device that projects images of stars, planets and other objects in space and their movement onto the surface of a round dome.

planetary sciences. The study of a planet or planets, what they are made of, how they are structured and their orbits.

pre-calculus. A math class taken to introduce calculus.

precipitate. To cause water vapor to become liquid and fall as rain or snow.

predict. To tell what you think will happen in the future.

pressure. The amount of force pushing on an object caused by the molecules surrounding it.

prism. A three-dimensional glass or crystal object with flat sides and edges that can break up light into separate colors, creating a spectrum.

probe. A device sent into space to explore and research objects.

property. A quality that defines a substance.

propulsion dynamics. The study of the forces that move, drive or propel an object forward.

protein. Building blocks of life that make up skin, fingernails and other plant and animal tissues. Proteins also help animals to digest food and perform many other important functions for life.

protostar. A young star that glows as gravity makes it collapse.

psychology. The study of how the brain processes information and how humans behave.

radiation. The transfer of energy by waves. Humans and other life forms can become very ill or even die from exposure to too much of certain types of radiation.

reactive. An element or substance that tends to easily interact with other elements or substances.

reactivity. The tendency to easily interact with other elements or substances.

red giant. A very large, bright, but cool star that normally has a temperature between 3,000°-6,000° Kelvin. After millions or even billions of years, when a main-sequence star has burned up the fuel in its core, it expands into a red giant.

red star. (red dwarf) A very cool, dim, small star that burns very slowly and has a surface temperature less than 3,500° Kelvin.

reproduction. The act of producing children or offspring.

respiration. The act or process of breathing.

restart. To start over.

role-play. To take on the role of another person. To pretend to be that person.
sensor. A device that detects and responds to a signal.

software. Computer programs that control how a computer functions.

dsolar flare. A burst of gases from a small area of the sun's surface that puts out intense radiation.

dsolar system. Our Sun and the objects that travel around it.

solid. A state of matter that has a definite shape and volume. In a solid, molecules are bonded together very tightly so that the solid keeps its shape or it is broken.

space science. Any of several sciences, such as astrobiology, that study occurrences and objects in space other than Earth.

specialist. A person who is an expert on a particular topic.

spectrometer. An instrument that measures spectra.

spectroscopy. The measurement and analysis of spectra.

spectrum. (pl. spectra) A rainbow or band of different colors made when light is broken up into wavelengths.

star. A large, hot ball of gases, which gives off its own light.

star system. A star and the objects that orbit around it.

star type. The category that a star fits into based on the features it shares with other stars in that category.

statistics. A type of math that involves collecting, organizing and interpreting numbers.

stratosphere. A layer of the Earth's atmosphere that is above the troposphere, between about 11 and 50 km above the Earth's surface.

submit. To send, give or turn in. In Astro-Venture, you click "Submit" to send your Astro Journal answers to scientists for review.

supergiant. Stars that are greater than ten times the mass of the Sun, expand into extremely large, bright stars called supergiants.

supernova. A star that explodes. Often a supernova is a supergiant that has become unstable.

surface effect. The effect on a small section of Earth as seen from the surface that occurs as a result of some change.

systems engineering. The use of math and science to design and build groups of connected parts that work together as a whole.

technical institute. A school that trains people in specific skills for certain occupations that use technology.

Tech Notes. In Astro-Venture, the Tech Notes give you background information and a glossary about the topics you select.

telescope. An instrument that collects light and makes distant objects appear larger and closer.

temperature. The measurement of how hot or cold something is.
thermal. Having to do with heat.

thermodynamics. The study of how heat moves.

trigonometry. A type of math that studies and compares angles in a right triangle.

trivia. Factual information that is not important but may be interesting to know.

troposphere. A layer of the Earth’s atmosphere that begins at Earth’s surface and extends to 11 km above the Earth’s surface.

ultraviolet radiation. Invisible radiation between visible violet light and X rays. Ultraviolet radiation causes sunburn and can harm life.

uninhabitable. Not fit to live in.

universe. All existing things, including Earth, the solar system and the galaxies.

university. A school where bachelor’s degrees, master’s degrees and doctorate degrees can be earned following high schools.

virus. A particle so small it can be seen only with a microscope and can reproduce inside a living cell.

vocational school. A school that trains people in specific skills for certain occupations.

volume. The amount of space an object takes up.

water vapor. The form water takes when it is a gas in the atmosphere.

wavelength. The distance from one peak to the next on a wave.

white dwarf. The end of a low mass star’s life, when the star’s core shrinks and its surface becomes white hot. These stars are very hot but dim.

yellow star. A medium-sized star that has a surface temperature between 5,000º-6,000º Kelvin.

zoology. The study of animals.
Appendix  Science and Career Resources

(Anchors) General Sciences/ Astrobiology/ Astronomy and Astrophysics/ Atmospheric Sciences/ Biology/ Careers/ Chemistry/ Computer Science/ Geology/ Engineering/ Management/ Mathematics/ Psychology

General Sciences

(Anchors) Curriculum Materials/ Events/ Museums, Science Centers and Field Trips/ Posters and Lithographs/ Speakers and Assemblies/ Videos and Slides/ Other Web Sites

Curriculum Materials

Ames Imaging Library Server (AILS)
http://ails.arc.nasa.gov/AILS.html
AILS is a living library of still images that chronicle the projects and activities of the NASA Ames Research Center. This site also provides links to other NASA image Web sites.

Central Operation of Resources for Educators (CORE)
http://core.nasa.gov
CORE serves as the worldwide distributor for NASA-produced multimedia materials. This includes a catalog of more than 200 videocassette, slide and CD-ROM programs.

Educator Resource Centers
http://www.jpl.nasa.gov/forum/erccenter.html
The ERCs provide educators with in-service and pre-service training demonstrations and access to NASA instructional materials suitable for use in the classroom. Much of the material is free; videotapes and slides may be copied. Resources include: curriculum materials, classroom activities, Internet access, lesson plans, computer programs, videos, 35 mm slides and publications.

NASA Spacelink
http://spacelink.nasa.gov
Spacelink is a NASA electronic resource specifically developed for use by the educational community and provides a wide variety of educational products - posters, lithographs, curriculum materials, multimedia resources (movie/audio clips.)
**Events**

**Botball**
http://rspacm1.arc.nasa.gov/botball/index.html
This program involves high school students, under the guidance of their teachers, and with consultation from members of the supporting organizations, in creating a mobile robot over four weeks to compete in a regional Botball tournament. Teachers and members of supporting organizations are involved in a three-day tutorial to learn robotic technology and integration into regular math and science curriculum prior to building the robots.

**JASON Project**
http://www.jason.org
JASON is a unique collaboration that utilizes telepresence technology to enable grade 3-9 classrooms to join in on and interact with ongoing research missions of the JASON team. Before implementing curriculum in the classroom and bringing students to Ames for the exciting broadcast and hands-on activities in the Spring, teachers must attend a one-day training in the Fall.

**NASA Student Involvement Program**
http://www.nsip.net
NSIP is a nationwide competition that encourages high school students to participate in NASA research topics. Students compete in the areas of engineering, computation, journalism and art. The winner of the supercomputer division receives a week-long internship at Ames to conduct research at the Numerical Aerodynamic Simulation Facility.

**Robotics FIRST**
http://www.usfirst.org
For Inspiration and Recognition of Science and Technology (FIRST) hosts high school students from fourteen Western States who design robots for this annual regional competition while gaining an inside look at the engineering profession. Students team up with engineers from businesses and universities for six weeks to brainstorm, design, construct and test their “champion robot.”

**Museums, Science Centers and Field Trips**

**American Association of Science and Technology Center**
http://www.astc.org
The Association of Science-Technology Centers Incorporated (ASTC) is an organization of science centers and museums dedicated to furthering the public understanding of science. ASTC encourages excellence and innovation in informal science learning by serving and linking its members worldwide and advancing their common goals. You can search for a science center near you. Resource center, professional development, publications and membership info.
Phone: (202) 783-7200
Posters and Lithographs

NASA CORE (Central Operation of Resources Educators)
http://core.nasa.gov
NASA CORE (Central Operation of Resources Educators) offers a wide variety of video tapes, slide sets, CD-ROM and Laserdiscs covering a variety of topics: i.e. aeronautics, earth science, careers, space sciences/exploration, energy, social sciences, life sciences and mathematics/physics, biology and history. phone: 440-775-1400, M-F, 8-4pm EST e-mail: nasaco@lee.ca.esu.k12.oh.us

NASA Spacelink
http://spacelink.nasa.gov
Spacelink is a NASA electronic resource specifically developed for use by the educational community and provides a wide variety of educational products – posters, lithographs, curriculum materials, multimedia resources (movie/audio clips.)

Speakers and Assemblies

Aerospace Education Service Program (AESP)
http://www.okstate.edu/aesp/AESP.htm
AESP is a program in which Aerospace Education Specialists provide school-based programs and services at school sites which include: staff development programs, lecture-demonstration programs for students and faculty, and curriculum development projects. The content includes earth science, space science, life science and aerospace transportation research and development discoveries and future plans. Due to the immense popularity of this program, a visit should be requested well in advance. There is no charge to schools for this program.

Speaker's Bureau
http://ccf.arc.nasa.gov/dx/SBsubjects.html
Speaker's Bureau provides speakers to educational institutions, business organizations, service clubs and professional and technical societies to speak on NASA and Ames Research Center programs. There is no fee for this service; however, reimbursement for transportation and per diem may be necessary. Please make requests at least six weeks in advance.

Videos and Slides

NASA CORE (Central Operation of Resources Educators)
http://core.nasa.gov
NASA CORE (Central Operation of Resources Educators) offers a wide variety of video tapes, slide sets, CD-ROM and Laserdiscs covering a variety of topics: i.e. aeronautics, earth science, careers, space sciences/exploration, energy, social sciences, life sciences and mathematics/physics, biology and history.
phone: 440-775-1400, M-F, 8-4pm EST e-mail: nasaco@lee.ca.esu.k12.oh.us
Other Web sites

ExInEd (Exploration In Education) Electronic Picture Book(s)
http://www.stsci.edu/exined/picturebooks.html
Electronic picture books on a variety of subjects. HyperCard Player 2.1 is needed “read” the picture books but is available to download for free on the Web site.

Learning Technologies Project (LTP)
http://learn.ivv.nasa.gov
NASA’s Learning Technologies Project (LTP) provides online, interactive, multimedia educational products derived from NASA Enterprise content. LTP projects increase public access to the storehouse of science that NASA has acquired as well as the data it is currently acquiring. LTP provides this content in accordance with the NASA Plan for Education by creating curriculum enhancements for K-12 and K-14 educators and delivering these materials via the Internet and other emerging technologies. LTP products are offered at about 5,000 (or 5%) of the schools nationwide.

NASA Spacelink
http://spacelink.nasa.gov
Spacelink is a NASA electronic resource specifically developed for use by the educational community and provides a wide variety of educational products – posters, lithographs, curriculum materials, multimedia resources (movie/audio clips.)

National Council of Teachers of Mathematics
http://wwwnctm.org
National organization dedicated to inform math teachers about NCTM and related topics and ideas.

National Science Teacher’s Association
http://www.nsta.org
National organization dedicated to inform science teachers about NSTA and related topics and ideas.

The Virtual Library
http://vlib.org
This site isn’t pretty, but it’s a quick way to find resources on all areas of science, education, engineering, humanities, law, recreation and many more!

ThinkQuest
http://www.thinkquest.org
Designed in 1996 to encourage the use of computer and network technology in education. Includes contests for students age 12-19 or grades 4-6 and a competition for student teachers, college and university faculty. ThinkQuest has brought together over 50,000 students and educators from 100 countries bringing together young people from widely divergent cultures and languages, levels of technology and socio-economic backgrounds.
Astrobiology

Books and Magazines

How to Build a Habitable Planet
Wallace S. Broecker, 1985
Traces the development of the Earth by describing the Big Bang, galaxy formation, star and planet formation, the Earth's segregation into layers, running water and temperature control and human civilization.

Life in the Universe
A. Operin and V. Fesenkov, 1961
This book deals with the question "Does life exist throughout the universe and in particular on the planets of our solar system?"

Mysteries of Life on Earth and Beyond
Franklyn M. Branley, 1987
ages 10-14
This book examines the significant research that is being done on life on Earth and beyond.
ISBN 0-525-67195-1

Other Worlds Is There Life Out There?
David J. Darling, 1985
children's book ages 9-12
This book examines the possibilities of finding life on nearby worlds.

Planets for Man
Stephen H. Dole and Isaac Asimov, 1964
This was one of the first astrobiology books written. It speculates on a time when human beings will be able to travel the vast distances to the other stars and attempts to determine—on the basis of the biological and cosmological knowledge of the time—whether there are other worlds where man can survive or where human life may even now be flourishing.
Rare Earth: Why Complex Life is Uncommon in the Universe
Peter D. Ward and Donald Brownlee, 2000
This book explains a new theory that these two astrobiologists formed of how they believe simple microbial life is common in the universe, but more complex life is rare.
ISBN 0-387-98701-0

The Search for Extraterrestrial Intelligence
Dennis B. Fradin, 1987
ages 9-12
Chronicles briefly scientific theories about and search for intelligent life beyond the Earth.

Career Resources and Professional Organizations

So You Want to be an Astrobiologist
http://www2.astrobiology.com/how.to.html
Definitions of Astrobiology and the questions that Astrobiologists research. Recommendations on how to become an Astrobiologist and books to read.

Curriculum Materials

Astrobiology: The Search for Life in Other Worlds
http://astrobio.terc.edu
A high school course curriculum being developed by TERC (a nonprofit research and development organization committed to Improving mathematics and science learning and teaching), NASA, and an advisory group of scientists and educators. Students use an inquiry-based, interdisciplinary approach to explore astrobiology.

ExoQuest
http://www.cotf.edu/ExoQues
A multimedia educational product for grades 7-9. With ExoQuest, students travel on virtual journeys to destinations in the solar system and beyond. Their trips are based on past, present, and future NASA missions. At each destination students conduct investigations that include hands-on and simulated experiments. Each investigation poses problems that focus on different areas of research, providing an interdisciplinary approach to science and the scientific method. The ExoQuest curriculum includes twelve activity modules.

SETI education
http://www.seti.org/education/Welcome.html
Voyages Through Time is a standards-based curriculum development project for an integrated one-year high school science course centered on the unifying theme of evolution. Learn how you can be involved in field testing. The Life in the Universe series is a set of six teacher’s guides for grades 3-9 that teach standards-based science around the theme of the search for extraterrestrial intelligence. Learn about the guides, and download sample lessons.
Other Web Sites

Astrobiology at NASA
http://astrobiology.arc.nasa.gov
Information on the goals and missions of astrobiology, educational resources and research updates.

Astrobiology: The Search for Life in Other Worlds
http://astrobio.terc.edu
A high school course curriculum being developed by TERC (a nonprofit research and development organization committed to Improving mathematics and science learning and teaching), NASA, and an advisory group of scientists and educators. Students use an inquiry-based, interdisciplinary approach to explore astrobiology.

ExoQuest
http://www.cotf.edu/ExoQuest
A multimedia educational product for grades 7-9. With ExoQuest, students travel on virtual journeys to destinations in the solar system and beyond. Their trips are based on past, present, and future NASA missions. At each destination students conduct investigations that include hands-on and simulated experiments. Each investigation poses problems that focus on different areas of research, providing an interdisciplinary approach to science and the scientific method. The ExoQuest curriculum includes twelve activity modules.

NASA Specialized Center of Research and Training NSCORT / Exobiology
http://exobio.ucsd.edu
A consortium between University of California, San Diego, The Scripps Research Institute (TSRI) and The Salk Institute (SALK.) The mission of this NSCORT is to conduct research in Exobiology; to train young scientists for research careers in Exobiology and related areas; and to communicate with scientists, students and the general public about the field of Exobiology.

New York Center for Studies on the Origins of Life
http://www.origins.rpi.edu/
Broadcast segments of WAMC's show "Origins of Life."

SETI education
http://www.seti.org/education/Welcome.html
Voyages Through Time is a standards-based curriculum development project for an integrated one-year high school science course centered on the unifying theme of evolution. Learn how you can be involved in field testing. The Life in the Universe series is a set of six teacher's guides for grades 3-9 that teach standards-based science around the theme of the search for extraterrestrial intelligence. Learn about the guides, and download sample lessons.

The Astrobiology Web
http://www.astrobiology.com
An online magazine about the latest events in astrobiology.
(Anchors) Books and Magazines/ Career Resources and Professional Organizations/ Hands-On Materials/ Speakers and Assemblies/ Student Camps and Clubs/ Videos and Slides/ Other Web Sites

Books and Magazines

1000 Facts About Space
Pam Beasant
Book Ages 9-12
ISBN 1856978117

Astronomy
http://www2.astronomy.com/astro
Magazine: News, events, subscription info, and product catalog.

Astronomy Smart Junior: The Science of the Solar System and Beyond
(Princeton Review Series) Michael L. Bentley
Book Ages 9-12
ISBN 0679769064

Color and Light
Book: 21 teacher written experiments and materials to help your classroom learn about light and color.
By Educational Insights

Make it Work! Space
Book: This book explores space from our planet Earth to the edge of the universe. It explains how planets and stars are formed and shows how to make simple instruments to observe them.

New Astronomer
Carole Stott
Book All Ages
Practical guide to finding and studying observable bodies - moon, sun, planets, comets, stars, star clusters, galaxies. Recent Hubble photos, etc.
ISBN 0789441756

Sky and Telescope
http://www.skypub.com/skytel/skytel.shtml
Magazine: Monthly magazine containing sky maps, astrophotos, and observation tips for sky-gazers of all levels.
To Space and Back
Written by Sally Ride
Book for All Ages
The first woman from the United States to enter space shares the personal experience of living and working while orbiting above Earth's atmosphere, unveiling the human side of space exploration.
ISBN 0688091121

Career Resources and Professional Organizations

American Astronomical Society
http://www.aas.org
Request a pamphlet with information on careers in astronomy.

American Institute of Physics
http://www.aip.org
Member organization which gives information on the advancement of the knowledge of physics and how it can be applied to human welfare.

The American Physical Society
http://www.aps.org
An organization of more than 42,000 physicists worldwide committed to advancing and diffusing the knowledge of physics. Publisher of three physics journals.

Hands-On Materials

Light Crystal Prism
(4.5") Use to split a beam of light into a multi-colored rainbow.
By TEDCO, Inc

Solar System Science Kit
Ages 8+ Broad range of lessons about astronomy, but mostly helps kids learn relative scale of planets by using kit to construct one scale model of the 9 planets.
By Educational Design
Speakers and Assemblies

Aerospace Education Service Program (AESP)
http://www.okstate.edu/aesp/AESP.html
AESP is a program in which Aerospace Education Specialists provide school-based programs and services at school sites which include: staff development programs, lecture-demonstration programs for students and faculty, and curriculum development projects. The content includes earth science, space science, life science and aerospace transportation research and development discoveries and future plans. Due to the immense popularity of this program, a visit should be requested well in advance. There is no charge to schools for this program.

Project Astro
http://aspsky.org/project_astro.html
An astronomer is matched to a classroom and makes four visits to this class during the school year.

Student Camps and Clubs

US Space Camp
http://www.spacecamp.com
Official site, with news on camp programs, plus images, sound clips, video, and other space links. Offers a variety of astronaut and fighter pilot training programs for children and adults at locations in Alabama, California, and Florida.

Videos and Slides

Contact
Video: A Warner Brothers movie starring Jodie Foster and Matthew McConnuhy

NOAA Corps: The Seventh Service
Video: Opportunities in Oceanography, Meteorology, Physics, Training Corp troops, sea duty and shore duty Grades: 9–12.
Accessible through the NASA CORE catalog at http://core.nasa.gov

Other Web Sites

Astronomical Society of the Pacific
http://www.aspsky.org
General info about ASP; catalog, membership, professional publications, annual meeting, astronomy education, and links.
Hubble Site  
http://hubble.stsci.edu  
The place to go to find out information about the Hubble telescope missions. Check out the latest news and a wonderful gallery of pictures.

NASA Office of Space Science  
http://spacescience.nasa.gov  
Information on NASA’s space missions.

Observatorium  
http://observe.ivv.nasa.gov  
NASA’s Observatorium is a public access site for Earth and space data. Visit this site to access pictures of the Earth, planets, stars, online activities, and lesson plans and the stories that go with each.

SETI Institute Online (the Search for Extraterrestrial Intelligence)  
http://www.seti.org  
General info on science, education, funding and membership relating to Extraterrestrial Intelligence.

SIRIF (Space Infrared Telescope Facility) Web Page  
http://sirtf.caltech.edu  
This site not only includes news and facts related to astronomy but also includes an excellent education and outreach section.

SOFIA (Stratospheric Observatory for Infrared Astronomy)  
http://sofia.arc.nasa.gov  
This site will include activities in science and education. A unique and important element SOFIA Education Program will be the Teacher Flight Program, which will provide opportunities for teachers to fly aboard the observatory, experience the research environment first-hand, interact closely with SOFIA science teams. SOFIA is expected to start science flights in 2002, and the SOFIA Education Program will become fully active at that time.

Space Telescope Science Institute Home Page – Hubble Space Telescope  
http://www.stsci.edu  
Information, education activities and a wealth of images from the Hubble Space Telescope.

The Planetary Society  
http://www.planetary.org  
A public organization that supports astronomy research and public education. Click the “Join Us” link at the top of the Home Page to become a member. Membership fees for US, Canadian and Int’l range from $15-$30 for students, $25-40 for general public. (En Español)  
65 North Catalina Ave Pasadena, CA 91106-2301  Phone: 1-800-WOW-MARS (1-800-969-6277)  Fax: (626) 793-5528  Email: tps@planetary.org
Yvonne Pendleton’s Astronomy Web site for students
http://web99.arc.nasa.gov/~yvonne
Yvonne and her work with Peterson Middle School and Laurelwood Elementary School, studying astronomy.

**Atmospheric Sciences**

(Anchors) Career Resources and Professional Organizations/ Videos and Slides/ Other Web Sites

**Career Resources and Professional Organizations**

American Chemical Society
http://www.acs.org
Information on chemistry careers, news, educational resources, and membership.

International Society of Biometeorology (ISB)
http://www.es mq.edu.au/ISB
Biometeorology is an interdisciplinary science studying the interaction between atmospheric processes and living organisms – plants, animals and humans.

**Other Web Sites**

AIRSITE
http://airsite.unc.edu
Atmospheric chemistry International Research Site for Information and Technology Exchange.

Ask Jack
http://www.usatoday.com/weather/askjack/wjack1.htm
Send Jack Williams a question about weather/climate and he and his team from USA Today will post replies on the Web site.

Atmospheric Chemistry Data and Resources from Goddard Space Flight Center
http://www.gsfc.nasa.gov
Information about the UARS (Upper Atmosphere Research Satellite), TOMS (Total Ozone mapping Spectrometer), SSBUV (Shuttle Solar Background Ultraviolet)—Data, ed. Resources, images, etc.

Atmospheric Chemistry Glossary
http://www.shsu.edu/~chemistry/Glossary/glos.html
Definitions of words related to atmospheric chemistry.
INSPIRE (Interactive NASA Space Physics Ionosphere Radio Experiments)
http://image.gsfc.nasa.gov/poetry/inspire
The INSPIRE Project has been involved in the investigation of very low frequency radio signals in the earth’s magnetosphere.

National Weather Service
http://www.nws.noaa.gov
Direct access to US official weather forecast products and observations (En Español)

The National Oceanic and Atmospheric Administration
http://www.noaa.gov
Photo library, visualizations in 3-D and virtual reality, climate and weather, maps, satellite images, employment opportunities and grant info, and webcasts.

(Biology)

(Career Resources and Professional Organizations/ Curriculum Materials/ Events/ Hands-On Materials/ Videos and Slides/ Other Web Sites)

Career Resources and Professional Organizations

American Institute of Biological Sciences
http://www.aibs.org/core/index.html
This professional organization includes more than 150,000 biologists dedicated to advancing research and education in the biological, medical, environmental and agricultural sciences.

American Physiological Society
http://www.faseb.org/aps
This organization is devoted to fostering scientific research, education and the dissemination of scientific information.

American Society for Biochemistry and Molecular Biology
Non-profit scientific and educational group. Primary activities include publishing the Journal of Biological Chemistry. Educational activities, educational resources, professional development, mentoring, employment and outreach. Free career brochure "Unlocking Life’s Secrets.”
9650 Rockville Pike, Bethesda, MD 20814 phone: 301-530-7417

American Society for Microbiology
http://www.asmusa.org
The American Society for Microbiology is the oldest and largest single life science membership organization in the world. It includes 42,000 members in 25 disciplines of microbiological specialization.
Biophysical Society
http://www.biophysics.org/biophys/society/biohome.htm
Resource for textbooks online, Biophysical Journal, Careers in Biophysics booklet, database of women and minority speakers. 9650 Rockville Pike, Bethesda, MD 20814

Biotechnology Industry Organization
http://www.bio.org/welcome.html
Represents biotech companies, academic institution and state biotech centers.

**Curriculum Materials**

STELLAR
http://stellar.arc.nasa.gov/stellar
STELLAR has a Web site: which contains over 60 activities in both English and Spanish. It has produced two CD’s Heart in Space and Vestibular System. It has also produced two editions of Space Life Express.

**Events**

Earth Day
http://www.sdearthtimes.com/edn
On April 22nd of each year, Earth day belongs to the public and isn’t run by any one group but there are several large non-profit groups and coalitions that gather info., and organize activities and events. The Earth Day Project Library is a good place to start.

**Hands-On Materials**

Nature’s Greenhouse
Four fascinating nature experiments and see-through greenhouse.
By Educational Insights

**Videos and Slides**

NOAA Corps: The Seventh Service
Accessible through the NASA CORE catalog at http://core.nasa.gov
Video: Opportunities in Oceanography, Meteorology, Physics, Training Corp troops, sea duty and shore duty Grades: 9—12.
Other Web sites

Biochemist online
http://www.biochemist.com
Publications - read or submit, chat rooms, job bank and resume services, resources.

NASA Office of Life and Microgravity Sciences and Applications (OLMSA)
http://www.hq.nasa.gov/office/olmsa
OLMSA leads the nation's efforts in life and microgravity sciences, related technology development, and applications using the attributes of the space environment to advance knowledge, to improve the quality of life on Earth, and to strengthen the foundations for continuing the exploration and utilization of space. Find out more about these NASA missions.

National Biological Information Infrastructure (NBII)
http://www.nbii.gov/index.html
The electronic gateway to biological data and information maintained by federal, state and local government agencies; private sector organizations; and other partners around the nation and the world.

National Biological Information Infrastructure (NBII) Education Page
http://www.nbii.gov/education/index.html
A resource for parents, teachers and students. Resources on all areas of biology—human, aquatic, mammalian and microbial biology; botany; biodiversity and environment.

Careers

Books and Magazines

Books and Magazines

Imagine: A Magazine for Talented Youth
http://www.jhu.edu/~gifted/set/imagine.html
Extracurricular activities, college planning, college reviews, exploring careers, book reviews, and fun stuff.

Events

National Engineers Week
http://www.ework.org
During National Engineers Week, take the opportunity to have an engineer from your community visit your classroom. Projects, resources, telecasts, how to volunteer and how to order materials.
1420 King Street Alexandria, VA 22314, 703-684-2852 email: eweek@nspe.org
**Posters and Lithographs**

**Superstars of Modern Aeronautics** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Poster: Features 12 significant people in Aeronautics Grades: 3—8

**Superstars of Spaceflight** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Poster: Features 15 astronauts Grades: 3—8

**Speakers and Assemblies**

**Aerospace Education Service Program (AESP)**
http://www.okstate.edu/aesp/AESP.html
AESP is a program in which Aerospace Education Specialists provide school-based programs and services at school sites which include: staff development programs, lecture-demonstration programs for students and faculty, and curriculum development projects. The content includes earth science, space science, life science and aerospace transportation research and development discoveries and future plans. Due to the immense popularity of this program, a visit should be requested well in advance. There is no charge to schools for this program.

**National Engineers Week**
http://www.eweek.org
During National Engineers Week, take the opportunity to have an engineer from your community visit your classroom. Projects, resources, telecasts, how to volunteer and how to order materials. 1420 King Street Alexandria, VA 22314, 703-684-2852 email: eweek@nspe.org

**Speaker's Bureau**
http://ccf.arc.nasa.gov/dx/SBsubjects.html
Speaker's Bureau provides speakers to educational institutions, business organizations, service clubs and professional and technical societies to speak on NASA and Ames Research Center programs. There is no fee for this service; however, reimbursement for transportation and per diem may be necessary. Please make requests at least six weeks in advance.

**Videos and Slides**

**Careers Aerospace Engineer** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Career profile of Greg Frazier, Mechanical engineer at Goddard Grades: 4+

**Engineers: Turning Ideas into Reality** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Short comments by engineers on why they chose their career Grades: 9+
Journey Into Cyberspace  (Accessible through the NASA CORE catalog)
http://careerjourney.vsgc.odu.edu
Video and Web: This video and Web site were produced by the Virginia Space Grant Consortium to encourage middle school students in math, science and technology. University students in the video demonstrate the opportunities available and increase student awareness about the wide-range of careers in engineering, science and high technology fields. Printed curriculum materials are also on the site.  Grades: 7-8

Looking up to your Aviation Career (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Careers in Aviation  Grades: 6+

NOAA Corps: The Seventh Service (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Opportunities in Oceanography, Meteorology, Physics, Training  Corp troops, sea duty and shore duty  Grades: 9—12

Preparing Today for Tomorrow (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Aerospace opportunities at NASA Langley  Grades: 4—8

Space for Women (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Opportunities for women at NASA  Grades: 9—12

Take the High Road (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Description and necessary education for careers in aerospace  Grades: 7—12

Video: Engineers: Turning Ideas Into Reality (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Offers a series of short commentaries by several engineers on why they chose their particular field of engineering and how they feel it impacts everyday life. Grades: 9-Adult

Where Dreams Come True (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: NASA career opportunities for minorities and women  Grades: 9—12

Winning: Aerospace the Next Decade (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Introduction to unique career opportunities in Aerospace  Grades: 7—12
Other Web Sites

Aero and Space Comic Book
http://graphix2.larc.nasa.gov/gs/samples/multi/022/022_00.html
Comic book with aerospace career scenarios.

ALLSTAR Network
http://www.allstar.fiu.edu/aero/career2.htm
Descriptions of Aeronautic careers and a matching quiz.

Bureau of Labor Statistics Career Information for Kids
http://stats.bls.gov/k12/html/edu_over.htm
Students can select a school subject they like, careers associated with that subject and find out details about these jobs.

Career Key
http://www.ncsu.edu/careerkey/
Find your Holland Codes based on Interests, Activities, Abilities, Statements and Values. The six personality types are: Realistic, Investigative, Artistic, Social, Enterprising, and Conventional.

Career Opportunities in Aerospace Technology
http://www.jsc.nasa.gov/ah/jscjobs/career/page1.htm
Descriptions of the types of work and appropriate fields of study for pursuit of NASA careers.

Careers in Aviation/Aerodynamics
http://wings.ucdavis.edu/Careers/index.html
Descriptions of aero careers.

CollegeView.com
http://www.collegeview.com/careers
This site includes online tests and tools such as Holland Code Types, Myers Briggs Type Indicator, California Psychological Inventory and the Armed Services Vocational Aptitude Battery to help students assess their personality type, interests, skills and values and to help them identify occupations that fit these.

Dictionary of Occupational Titles
http://www.wave.net/upg/immigration/dot_index.html
The U.S. Department of Labor by: specific career title; number; term titles and definitions; occupational categories, divisions, and groups; explanation of data, people, and things; and components of the definition trailer.

Earth Science Careers in NASA
http://kids.earth.nasa.gov/archive/career/index.html
Summaries of earth science professions.
EBiz4Teens
http://library.thinkquest.org/28188/index2.htm
Three students who participated in ThinkQuest (www.thinkquest.org) International Internet Challenge designed this Web site. The Web site was designed by teens for teens that are interested in taking their creative ideas and starting their own eBusiness. Read about the basics of eBusiness, starting your own eBusiness, the History and evolution of eBusiness and exciting success stories.

Extreme Science
http://www.extremescience.com
Descriptions of scientists and animated fieldwork settings.

Jobs with the Federal Government
http://www.usajobs.opm.gov
Current job openings and descriptions, information on applying, intern programs, student employment, salaries and benefits.

John Hopkins University – Center for Talented Youth
http://www.jhu.edu/~gifted
An academic and career guidance assessment can be done through the mail for a fee of $175.

Meet the people who...
http://pao.gsfc.nasa.gov/gsfc/people/meet.htm
Biographies of various Center employees.

NASA Astronaut Biographies
http://www.jsc.nasa.gov/er/she/index.htm
Astronaut biographies.

NASA Facts
http://www.dfrc.nasa.gov/trc/careers/index.html
Summaries of several Dryden Flight Research Center jobs

NASA Glenn Biographies
Biographies of Center and other leaders.

Occupational Outlook Handbook
http://stats.bls.gov/oco/home.htm
How to find information about specific occupations by: performing a keyword search, using the index, or selecting from an occupational cluster.

NASA Quest
http://quest.arc.nasa.gov
NASA bios and journals, chats, aero, space and women.
Space Academy
http://liftoff.msfc.nasa.gov/academy/astronauts/wannabe.html
Information on becoming an astronaut.

Spacelink
Links to NASA and external career-related sites.

Take Off!
http://www.mcet.edu/nasa/index.html
Aero and aviation careers album.

Women and Minorities

Consider a Career in Aerospace (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Poster: This poster was developed as a tool to encourage young women to pursue careers in mathematics, science, engineering and technology. It provides information and activities for educators to use with their students relating to past, present and future careers in aerospace.

Space for Women (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Opportunities for women at NASA Grades: 9—12

Where Dreams Come True (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: NASA career opportunities for minorities and women Grades: 9—12

Women of NASA
http://quest.arc.nasa.gov/women/intro.html
Web site: Women of NASA features biographies, journals, chats and Web casts of women who work at NASA.
Resources

Chemistry

Biochemistry *(See Biology)*
Atmospheric Chemistry *(See Atmosphere)*

(Anchors) Career Resources and Professional Organizations/ Other Web Sites

Career Resources and Professional Organizations

American Chemical Society
http://www.acs.org
Information on chemistry careers, news, educational resources, and membership.

American Institute of Chemical Engineers
http://www.aiche.org
Information on conferences, publications, careers, education and training for those interested in chemical engineering.

Other Web Sites

Chemical Engineers’ Resource Page
http://www.cheresources.com/indexzz.shtml
Includes articles and information related to chemical engineering.

History of Chemical Engineering & Chemical Technology
http://www3.cems.umn.edu/~aiche_ug/history/h_intro.html
Information on the growth and change in the chemical industry, the chemical engineering profession, and its educational infrastructure.

Computer Science

(Anchors) Books and Magazines/ Career Resources and Professional Organizations/ Videos and Slides/ Other Web Sites

Books and Magazines

Byte
http://www.byte.com
Magazine about computers

MacWorld
http://macworld.zdnet.com
Magazine about Macintosh computers
Resources

PC World
http://www.pcworld.com
Magazine about PC computers

Career Resources and Professional Organizations

Association for Computing Machinery (ACM)
http://www.acm.org
World’s first education and scientific computing society. Articles, conferences, career opportunities. 1515 Broadway, New York, NY 10036

IEEE Computer Society
http://www.computer.org
Technical and career resources for computer professionals. (members, students and employers), job listings, resume posting and info on continuing education and certification. Headquarters Office, 1730 Massachusetts Ave., NW, Washington DC 20036-1992

Videos and Slides

Video and Web: Journey Into Cyberspace (Accessible through the NASA CORE catalog)
http://careerjourney.vsgc.odu.edu
This video and Web site were produced by the Virginia Space Grant Consortium to encourage middle school students in math, science and technology. University students in the video demonstrate the opportunities available and increase student awareness about the wide-range of careers in engineering, science and high technology fields. Printed curriculum materials are also on the site. Grades: 7-8.

Other Web Sites

Biochemist online
http://www.biochemist.com
Publications - read or submit, chat rooms, job bank and resume services, resources
(Anchors) Career Resources and Professional Organizations/ Events/ Posters and Lithographs/ Speakers and Assemblies/ Videos and Slides/ Other Web Sites

**Career Resources and Professional Organizations**

**Aero and Space Comic Book**
http://graphix2.larc.nasa.gov/gs/samples/multi/022/022_00.html
Comic book with aerospace career scenarios.

**ALLSTAR Network**
http://www.allstar.fiu.edu/aero/career2.htm
Descriptions of Aeronautic careers and a matching quiz.

**American Institute of Aeronautics and Astronautics**
http://www.aiaa.org
AIAA - primary purpose is to advance the arts, sciences, and technology of aeronautics and astronautics, and to foster promote the professionalism of those engaged in these pursuits.
Inc. Suite 500, 1801 Alexander Bell Drive, Reston, VA  20191-4344

**Careers in Aviation/Aerodynamics**
http://wings.ucdavis.edu/Careers/index.html
Descriptions of aero careers.

**For Inspiration and Recognition of Science and Technology (FIRST)**
http://www.usfirst.org
Look here for Robotics FIRST info. A non-profit organization whose mission is to generate an interest in science and engineering among today’s youth. Primary means of accomplishing this goal is through annual robot competitions, which began in 1992. We are also in the process of opening a science and technology facility in downtown Manchester, NH.

**Institute of Electrical and Electronics Engineers**
http://www.ieee.org
Non-profit, technical professional association. Leading authority in tech areas ranging from computer engineering, biomedical technology and telecommunications, to electric power, aerospace and consumer electricity and produces 30% of the world's published literature in elec. Eng., computer and control technology. Includes educational opportunities, student branches, and advocacy for women and ethics. 1828 L St. NW Suite 1202, Washington, DC  20036

**Junior Engineering Technical Society**
http://www.jets.org
Resource for pre-college engineering information.
NASA Facts
http://www.dfrc.nasa.gov/trc/careers/index.html
Summaries of several Dryden Flight Research Center jobs

Society of Manufacturing Engineers
http://www.sme.org
Provides manufacturing information, standards, conferences, education, and services to manufacturing professionals. Conferences/Competitions, book and video resources, Grants/scholarships, certification/professional licensure info.  One SME Drive, P.O. Box 930, Dearborn, MI 48121-0930

Take Off!
http://www.mcet.edu/nasa/index.html
Aero and aviation careers album

Events

Botball
http://rspacm1.arc.nasa.gov/botball/index.html
This program involves high school students, under the guidance of their teachers, and with consultation from members of the supporting organizations, in creating a mobile robot over four weeks to compete in a regional Botball tournament. Teachers and members of supporting organizations are involved in a three-day tutorial to learn robotic technology and integration into regular math and science curriculum prior to building the robots.

National Engineers Week
http://www.eweek.org
During National Engineers Week, take the opportunity to have an engineer from your community visit your classroom. Projects, resources, telecasts, how to volunteer and how to order materials.  1420 King Street Alexandria, VA 22314, 703-684-2852  email: eweek@nspe.org

Robotics FIRST
http://www.usfirst.org
For Inspiration and Recognition of Science and Technology (FIRST) hosts high school students from fourteen Western States who design robots for this annual regional competition while gaining an inside look at the engineering profession. Students team up with engineers from businesses and universities for six weeks to brainstorm, design, construct and test their “champion robot”
Posters and Lithographs

**Poster: Superstars of Modern Aeronautics** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Features 12 significant people in Aeronautics Grades: 3—8

Speakers and Assemblies

**National Engineers Week**
http://www.eweek.org
During National Engineers Week, take the opportunity to have an engineer from your community visit your classroom. Projects, resources, telecasts, how to volunteer and how to order materials. 1420 King Street Alexandria, VA 22314, 703-684-2852 email: eweek@nspe.org

Videos and Slides

**Careers Aerospace Engineer** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Career profile of Greg Frazier, Mechanical engineer at Goddard Grades: 4+

**Engineers: Turning Ideas into Reality** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Short comments by engineers on why they chose their career Grades: 9+

**Engineers: Turning Ideas Into Reality** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Offers a series of short commentaries by several engineers on why they chose their particular field of engineering and how they feel it impacts everyday life. Grades: 9–Adult

**Journey Into Cyberspace** (Accessible through the NASA CORE catalog)
http://careerjourney.vsgc.odu.edu
Video and Web: This video and Web site were produced by the Virginia Space Grant Consortium to encourage middle school students in math, science and technology. University students in the video demonstrate the opportunities available and increase student awareness about the wide-range of careers in engineering, science and high technology fields. Printed curriculum materials are also on the site. Grades: 7–8.

**Looking up to your Aviation Career** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Careers in Aviation Grades: 6+

**Preparing Today for Tomorrow** (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Aerospace opportunities at NASA Langley Grades: 4—8
Take the High Road  (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Description and necessary education for careers in aerospace Grades: 7—12

Winning: Aerospace the Next Decade  (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Introduction to unique career opportunities in Aerospace Grades: 7—12

Other Web Sites

Discover Engineering Online
http://www.discoverengineering.org/eweek/index.html
A Web site designed especially for grades 6-9 and brought to you by National Engineer's Week. Variety of resources downloads trivia and more!

For Inspiration and Recognition of Science and Technology (FIRST)
http://www.usfirst.org
*Look here for Robotics FIRST info. A non-profit organization whose mission is to generate an interest in science and engineering among today’s youth. Primary means of accomplishing this goal is through annual robot competitions, which began in 1992. We are also in the process of opening a science and technology facility in downtown Manchester, NH.

KISS Institute for Practical Robotics (KIPR)
http://www.kipr.org
*Look here for Botball information.
Lindsey Square Bldg. D, STE 100 1818 W. Lindsey Norman, OK 73069 Phone: (405) 325-7864 Fax: (405) 325-7797 Email: kipr@kipr.org

Robotics Education Program (REP)
http://robotics.arc.nasa.gov
REP is your NASA source for K-12 robotics education. REP organizes robotic competitions and will be offering online robotics courses and labs for credit in the future.
Atmosphere and Weather (See Atmosphere)

(Anchors) Books and Magazines/ Career Resources and Professional Organizations/ Events/ Hands-On Materials/ Videos and Slides/ Other Web Sites

Books and Magazines

Dr. Art’s Guide to Planet Earth
Art Sussman, Ph.D. 2000
ages 12+
This book describes Earth as a whole system made up of three main parts and how they work together: matter, energy and life.

This Dynamic Earth: The Story of Plate Tectonics
W. Jacqueline Kious and Robert I Tilling U.S. Geological Survey
This booklet gives a brief introduction to the concept of plate tectonics with excellent illustrations and photographs.ISBN 0-16-048220-8

Career Resources and Professional Organizations

Earth Science Careers in NASA
http://kids.earth.nasa.gov/archive/career/index.html
Summaries of earth science professions.

Events

Earth Day
http://www.sdearthtimes.com/edn
On April 22nd of each year, Earth day belongs to the public and isn’t run by any one group but there are several large non-profit groups and coalitions that gather info, and organize activities and events. The Earth Day Project Library is a good place to start.

Hands-On Materials

Hands-On Nature Adventures – Rocks
Explore rock and mineral properties, classification with 16 authentic specimens. Id charts and magnifying glass included.
By Educational Insights
Lunar Samples
Lunar rock and regolith samples are made available for classroom use through the NASA Education Resource Centers (http://www.jpl.nasa.gov/forum/erccenter.html). Six samples of rocks and regolith are embedded in a 15-cm diameter plastic disk. Disks are sent via registered mail to educators for one- to two-week loan periods. The package also includes this book Exploring the Moon, an annotated slide set of lunar images (described more fully on Page v), and a collection of color photographs and descriptions of the six samples.

Smithsonian Smarlabs Volcano
Build and erupt your very own volcano using non-toxic chemicals. Real volcanic rocks included.

Videos and Slides

NOAA Corps: The Seventh Service (Accessible through the NASA CORE catalog)
http://core.nasa.gov
Video: Opportunities in Oceanography, Meteorology, Physics, Training Corp troops, sea duty and shore duty Grades: 9—12

Other Web Sites

Ask-A-Geologist
http://walrus.wr.usgs.gov/docs/ask-a-ge.html
e-mail your earth science question to a US Geological Survey earth scientist

Geologylink
http://www.geologylink.com
Daily geo-news updates, discussion forums, an expansive directory of links, virtual field trips, geology classes and a glossary.

Global Learning and Observations to Benefit the Environment (GLOBE)
http://www.globe.gov
GLOBE is a worldwide science and education program coordinating the work of students, teachers and scientists to study and understand the global environment. GLOBE students make environmental observations at or near their schools and report their data through the Internet. Scientists use GLOBE data in their research and provide feedback to the students to enrich their science education. Global images based on GLOBE student data are displayed on the World Wide Web, enabling students and other visitors to visualize the student environmental observations.
NASA Office of Earth Science  
http://www.hq.nasa.gov/office/mtpe/  
Information on NASA’s Earth science missions, research, latest news and related educational resources.

NASA/USGS Planetary Geologic Mapping Program  
http://wwwflag.wr.usgs.gov/USGSFlag/Space/GEOMAP/PGM_home.html  
Geologic mapping investigation of imaged planetary bodies (except Earth).

U.S. Geological Survey Home Page  
http://www.usgs.gov  
Find picture and detailed maps, search the library and research fascinating topics in Earth Science like earthquakes, floods, volcanoes and more!

Management

(Anchors) Career Resources and Professional Organizations/ Student Camps and Clubs/

Career Resources and Professional Organizations

American Management Association  
http://www.amanet.org/index.htm  
AMA is a membership-based management development organization. AMA offers a full range of business education and management development programs for individuals and organizations in Europe, the Americas and Asia. Through a variety of seminars and conferences, assessments and customized learning solutions, books and on-line resources, more than 700,000 AMA members and customers a year learn superior business skills and best management practices from a faculty of top practitioners.  
1601 Broadway, New York, NY 10019-7420

National Management Association  
http://www.nma1.org  
The only association of its kind, devoted to the personal and professional development of America’s workforce.  
2210 Arbor Blvd. Dayton, OH 45439

Student Camps and Clubs

Junior Achievement, Inc.  
http://www.ja.org  
JA educates and inspires young people to value free enterprise, business and economics to improve the quality of their lives. Activities educate them about business and economics and help prepare them for fulfilling careers.  
One Education Way Colorado Springs, CO 80906 Phone: 719-540-8000
National Council on Youth Leadership  
http://www.ncyl.org  
NCYL is a non-profit organization dedicated to the belief that the recognition, encouragement and leadership skills we give to young men and women today serve as a powerful inspiration that can shape their behavior in tomorrow’s world.  
Phone: 888-462-9598

Toastmasters International  
http://www.toastmasters.org  
Toastmasters is the best way to improve your communication skills. Their club can help you lose the fear of public speaking and learn skills that will help you be more successful in every path of life/career.

Mathematics

(Anchors) Career Resources and Professional Organizations/ Student Camps and Clubs/ Other Web Sites

Career Resources and Professional Organizations

American Mathematical Society  
http://www.ams.org  
Founded in 1888 to further mathematical research and scholarship. Job search, meetings, membership info, education, scholarships, job-hunting advice, and info on math camps for high school students.  
Department of Professional Programs and Services, P.O. Box 6248, Providence, RI 02940-6248

Mathematical Association of America  
http://www.maa.org/  
Memberships, news, student chapters, professional development, book reviews, employment opportunities.  
1529 18th St. NW, Washington D.C. 20036

Society for Industrial and Applied Mathematics  
The organization of applied mathematics and computational scientists dedicated to enriching our profession through publications, conferences, activity groups and programs since 1952.  
3600 University City Science Center, Philadelphia, PA 19104-2688  
phone: 215-382-9800
**Student Camps and Clubs**

Mu Alpha Theta  
[http://mualphatheta.org/what.html](http://mualphatheta.org/what.html)
This organization is a national high school and junior and community college mathematics club for honors students who participate in various activities such as state competitions, annual conventions or tutoring.

**Other Web Sites**

National Council of Teachers of Mathematics  
[http://www.nctm.org](http://www.nctm.org)
Organization of math instructors to ensure excellent mathematics education for all students. This site includes information on the national mathematics education standards, conferences and publications.

**Career Resources and Professional Organizations**

American Psychological Association  
The APA is the largest scientific and professional organization representing psychology in the United States and has more than 159,000 members. This site includes career planning information, education programs and college summer programs.

National Association of School Psychologists  
[http://www.naswweb.org](http://www.naswweb.org)
Promoting educationally and psychologically healthy environments for all children and youth.

National Mentoring Partnership  
[http://www.mentoring.org](http://www.mentoring.org)
The National Mentoring Partnership is an advocate for the expansion of mentoring and a resource for mentors and mentoring initiative nationwide.