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Educator Product	
Educators	Grades 5-8

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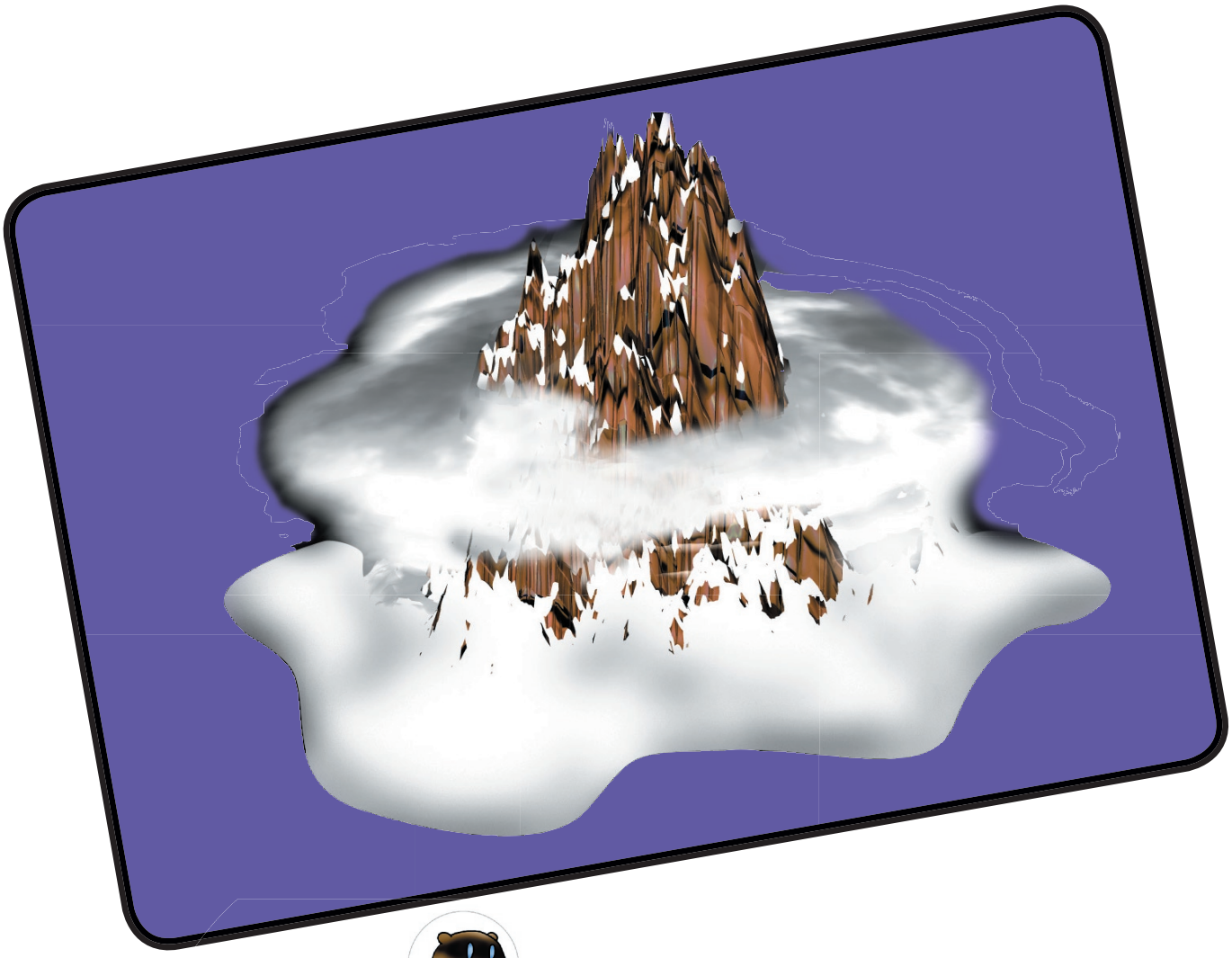
Astro-Venture: Atmospheric Science Educator Guide

An Educator Guide with Activities in Atmospheric Sciences and Astrobiology



http://astroventure.arc.nasa.gov

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Astro-Venture: Atmospheric Science Educator Guide

National Aeronautics and Space Administration
Office of Education

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EDCATS Educator Reply Card

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Introduction

The Astro-Venture Atmospheric Science Educator Guide has 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.

The Astro-Venture Atmospheric Science Educator Guide and online activities are designed to follow the Astro-Venture Astronomy Educator Guide and online modules. It is possible to take students through the Atmosphere unit without having completed the Astronomy section; however, it is assumed that educators will make sure that their students have mastered the prerequisite concepts prior to introducing these lessons. In particular, educators should consider implementing Astronomy Lesson 1: Unit Introduction and Astronomy Lesson 7: Thinking in Systems, as these two lessons introduce unifying concepts to which connections are made throughout Astro-Venture.

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 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 NASA Career Fact Sheets, trading cards, and NASA Quest challenges (http://quest.nasa.gov) in which students engage in design problems or explorations supported by NASA scientists who provide answers to questions and feedback on solutions via Web chats and webcasts (live streaming audio and video).

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

1. Students in grades 5-8 will be able to identify and explain the vital characteristics of Earth that make it habitable to humans.

2. 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.

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

4. 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 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 Science
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 change aspects of our Solar System and planet 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, the flow of energy 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 science 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 Atmospheric Science Educator Guide is written to meet benchmarks found in 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).[1] "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)[2] 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, and then the number of the concept under this standard and grade range. We distinguish between "meeting" benchmarks or standards, "partially meeting" them, and "addressing" them to alert educators to concepts that are taught or partially taught for deep understanding in a lesson or lessons compared to topics or ideas that we might touch upon but do not really teach for deep understanding. 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)[3].

[1] Project 2061, American Association for the Advancement of Science. (1993). Benchmarks for Science Literacy. New York. Oxford University Press. (p. VII).
[2] Project 2061. (p. XI).
[3] Project 2061. (p. XI).

Example of Lesson Objectives/Standards Table

Objectives:	Standards:
• Students will research and list in their Astro Journals the necessities for human survival. • They will write a story about human survival identifying these necessities, how they are met, and the consequences of not meeting them. • After comparing characteristics of the Earth with other planets and moons, students will predict the features of Earth that they believe are crucial to human survival.	Meets: 2061: 6C (3-5) #1, 2 Addresses: 2061: 4B (6-8) #2

In addition to meeting benchmarks, the Astro-Venture Atmospheric Science Educator Guide integrates 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.

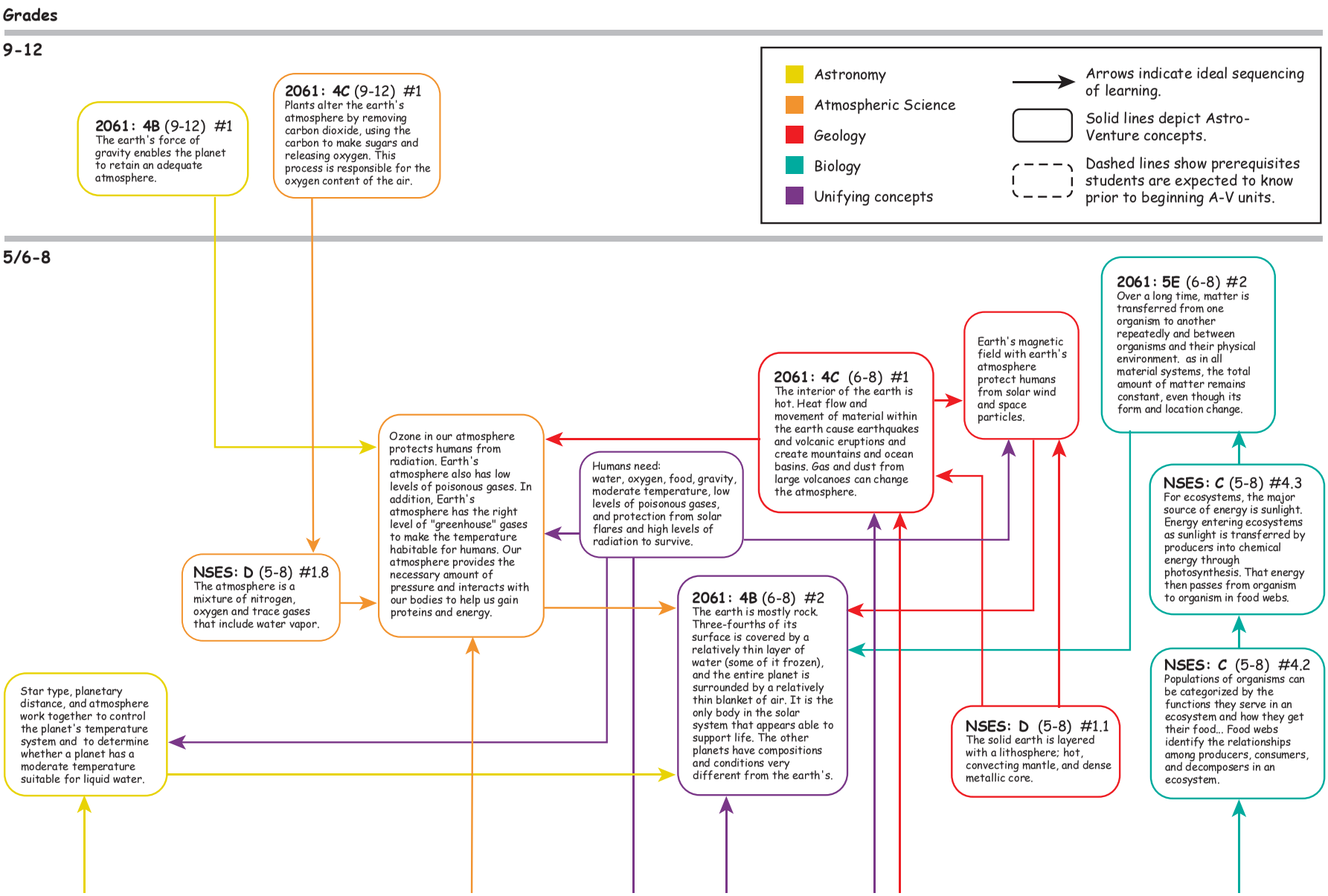
Astro-Venture Concept Map

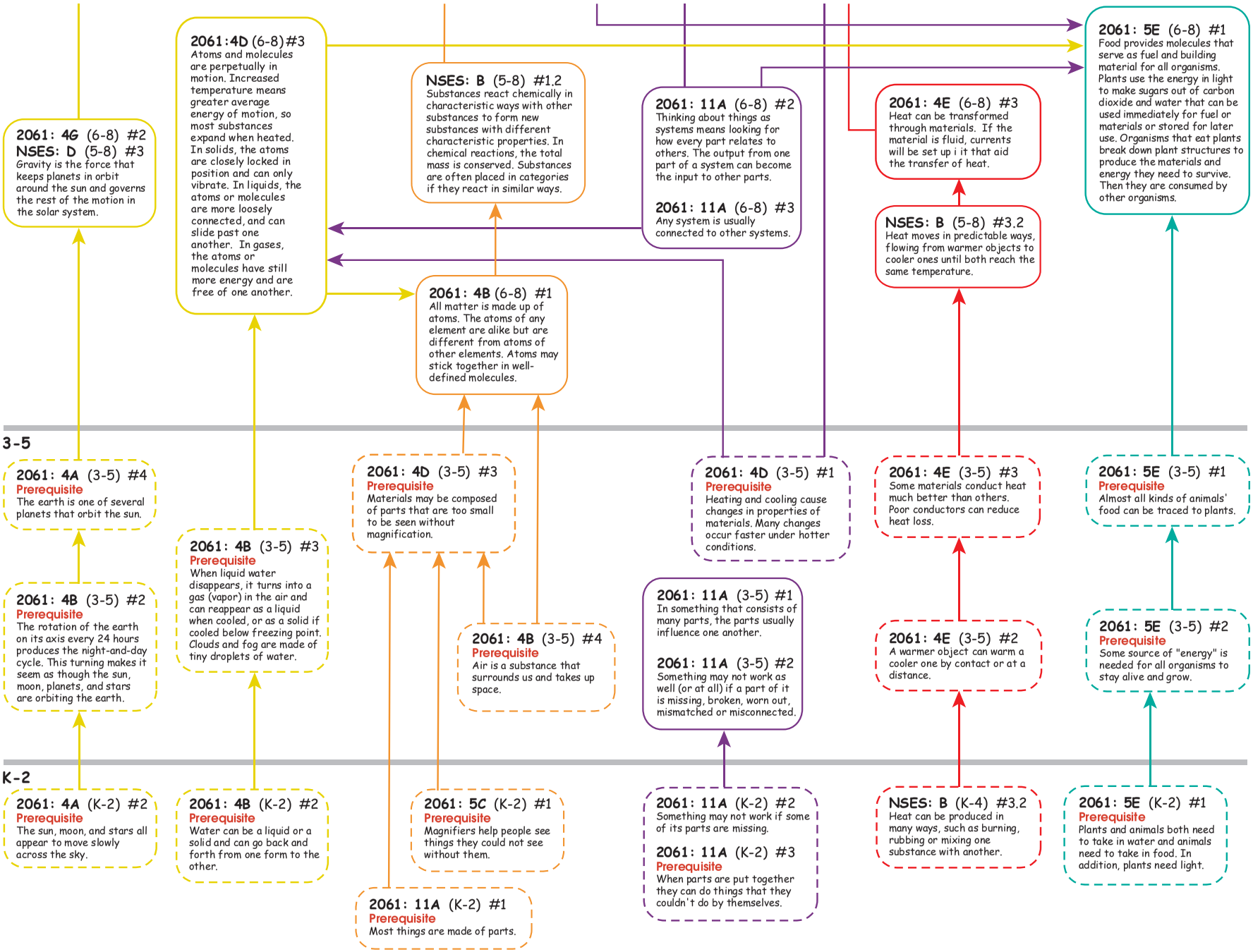
The map on the following two pages demonstrates the Benchmarks for Science Literacy and National Science Education Standards that have been identified for Astro-Venture. The map shows the overall concepts that are taught throughout Astro-Venture, as well as the benchmarks specific to the different sections. 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:

Standard/Benchmark Title	Web Address
American Association for the Advancement of Science: Project 2061	http://www.project2061.org/
National Science Education Standards (NSES)	http://www.nap.edu/readingroom/books/nses/html/
National Council of Teachers on Mathematics (NCTM)	http://standards.nctm.org/index.htm
International Society for Technology in Education (ISTE)	http://cnets.iste.org/
International Technology Education Association (ITEA)	http://www.iteawww.org/TAA/TAA.html

Astro-Venture Concept Map




2061: 4G (6-8) #2
NSES: D (5-8) #3
Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system.
2061:4D (6-8)#3
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) #1.2
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.
2061: 11A (6-8) #2
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.
2061: 11A (6-8) #3
Any system is usually connected to other systems.
2061: 4E (6-8) #3
Heat can be transformed through materials. If the material is fluid, currents will be set up i it that aid the transfer of heat.
2061: 5E (6-8) #1
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 that can be used immediately for fuel or materials or 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.
NSES: B (5-8) #3.2
Heat moves in predictable ways, flowing from warmer objects to cooler ones until both reach the same temperature.
2061: 4B (6-8) #1
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.
3-5
2061: 4A (3-5) #4
Prerequisite
The earth is one of several planets that orbit the sun.
2061: 4B (3-5) #3
Prerequisite
When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below freezing point. Clouds and fog are made of tiny droplets of water.
2061: 4D (3-5) #3
Prerequisite
Materials may be composed of parts that are too small to be seen without magnification.
2061: 4D (3-5) #1
Prerequisite
Heating and cooling cause changes in properties of materials. Many changes occur faster under hotter conditions.
2061: 4E (3-5) #3
Some materials conduct heat much better than others. Poor conductors can reduce heat loss.
2061: 5E (3-5) #1
Prerequisite
Almost all kinds of animals' food can be traced to plants.
2061: 4B (3-5) #2
Prerequisite
The rotation of the earth on its axis every 24 hours produces the night-and-day cycle. This turning makes it seem as though the sun, moon, planets, and stars are orbiting the earth.
2061: 4B (3-5) #4
Prerequisite
Air is a substance that surrounds us and takes up space.
2061: 11A (3-5) #1
In something that consists of many parts, the parts usually influence one another.
2061: 11A (3-5) #2
Something may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected.
2061: 4E (3-5) #2
A warmer object can warm a cooler one by contact or at a distance.
2061: 5E (3-5) #2
Prerequisite
Some source of "energy" is needed for all organisms to stay alive and grow.
K-2
2061: 4A (K-2) #2
Prerequisite
The sun, moon, and stars all appear to move slowly across the sky.
2061: 4B (K-2) #2
Prerequisite
Water can be a liquid or a solid and can go back and forth from one form to the other.
2061: 5C (K-2) #1
Prerequisite
Magnifiers help people see things they could not see without them.
2061: 11A (K-2) #1
Prerequisite
Most things are made of parts.
2061: 11A (K-2) #2
Something may not work if some of its parts are missing.
2061: 11A (K-2) #3
Prerequisite
When parts are put together they can do things that they couldn't do by themselves.
NSES: B (K-4) #3.2
Heat can be produced in many ways, such as burning, rubbing or mixing one substance with another.
2061: 5E (K-2) #1
Prerequisite
Plants and animals both need to take in water and animals need to take in food. In addition, plants need light.

Astro-Venture Atmospheric Science Section

In the Atmospheric Science section, students begin as Junior Atmospheric Chemists where they complete the online Atmospheric Science Training module to discover the atmospheric conditions that make Earth habitable to humans. When they have successfully completed their training, they earn their certificate and are promoted to Senior Atmospheric Chemist. They then engage in off-line Atmospheric Science lessons to discover why we need the atmospheric conditions identified in Atmospheric Science Training and are introduced to some basic chemistry concepts. The unit concludes with students connecting their new knowledge to systems they explored in the Astronomy unit and summarizing their learning through the development of superheroes based on elements who save the world by combining their powers to form important gases in the atmosphere.

Astro-Venture Atmospheric Science Lessons, Objectives and Standards Alignment

Unit Concept: The atmosphere helps make Earth habitable to humans by maintaining Earth's surface temperature, protecting life from harmful ultraviolet radiation, providing the necessary amount of pressure, and interacting with our bodies to help us to gain proteins and energy through the process of chemical change.

Overview of the Atmospheric Science unit: Using an online, multimedia module, students change the amounts of gases in our atmosphere and draw conclusions about which factors are necessary for human survival. Students then engage in classroom activities that help them to form an understanding of atoms, elements, and molecules as the components of gases that have unique properties that makes each gas important to human survival. Students further explore the process of chemical change, with a focus on some of the chemical reactions most important to human survival. In contrast, they learn how the inert gas, nitrogen, is important to human life by contributing to our surface pressure. Finally, they connect their learning to the systems they explored in Astronomy.

The objectives and standards of Astro-Venture Atmospheric Science are broken down into eight lessons, as shown in the table on the following two pages.

Lesson	Main Concept	Scientific Question	Objective	Benchmarks/ Standards
1. Atmospheric Science Training Module	Certain atmospheric conditions help to support human survival.	What atmospheric conditions are required for human survival?	• Students make changes to our atmosphere and write descriptive, objective observations of the effects of these changes on Earth. • Students will identify the characteristics of our atmosphere that are required to allow for human survival.	**Meets**: NSES: A (5-8) #1 ISTE: 3, 5 **Partially meets**: NSES: D (5-8) #1.8 **Addresses**: 2061: 4B (6-8) #2
2. Building Blocks of Matter	All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.	What are the building blocks of matter? What are their properties? How do they behave?	• Students will explain that the atoms of any element are alike and have the same properties and characteristics but are distinct from atoms of other elements. • Students will show how atoms can be grouped into molecules.	**Meets**: 2061: 4D (6-8) #1 **Partially meets**: NSES: B (5-8) #1.3 NSES: B (9-12) #1.1 NSES: B (9-12) #2.2
3. Greenhouse Gases: Carbon Dioxide and Water Vapor	Carbon dioxide and water vapor are greenhouse gases that absorb energy radiated from Earth's surface and release some of it back towards the Earth, increasing the surface temperature.	What are greenhouse gases? How do the unique properties of greenhouse gases affect a planet and human life?	• Students will identify CO_2 and H_2O as greenhouse gases and explain that these gases absorb energy radiated from Earth's surface and release some of it back towards the Earth, increasing the surface temperature.	**Partially meets**: 2061: 4E (6-8) #3 **Addresses**: NSES: B (5-8) #3.1 NSES: B (5-8) #3.2 NCTM: 5, 9
4. The Flow of Matter: Chemical Change and Conservation of Matter	When substances interact and new substances are created, chemical change has occurred. Matter is neither created nor destroyed in this process.	What is the process of chemical change? How does this process affect matter?	• Students will explain how molecules may be broken apart and the atoms reorganized into new molecules that have different properties. • Students will demonstrate that when chemical changes occur, matter is transferred but not created or destroyed.	**Partially meets**: 2061: 4D (6-8) #7 2061: 4D (3-5) #4 NSES: B (5-8) #1.2 **Addresses**: NCTM: 4, 5, 9
5. Oxygen,	Oxygen is a highly reactive element involved in chemical reactions that release heat energy. Oxygen is important to humans because it helps to convert sugars into energy in the cells.	How does oxygen interact with other elements and molecules? How do these unique interactions affect human life?	• Students identify oxygen as a reactive element that benefits humans by helping to convert sugars into energy in the cells. • Students explain combustion as a chemical reaction.	**Partially meets**: 2061: 4D (6-8) #6 NSES: B (5-8) #3.5 **Addresses**: 2061: 5C (6-8) #3 NSES: C (5-8) #1.3 NCTM: 4, 5, 9

Lesson	Main Concept	Scientific Question	Objective	Benchmarks/ Standards
6. Strato-spheric Ozone and Ultravio-let Light	The creation and destruction of ozone in the stratosphere protects life on Earth from harmful ultra-violet radiation.	How does ozone protect life on Earth from ultraviolet radiation?	• Students will explain and diagram how ozone is created and destroyed in the stratosphere due to ultraviolet radiation from the Sun. • Students will explain the consequences of overexposure to ultraviolet radiation. • Students will explain how certain substances interfere in the ozone creation/destruction process and allow more ultraviolet radiation to strike Earth's surface.	**Addresses**: NSES: B (5-8) 3.6 NSES: B (5-8) 1.1 NSES: F (5-8) 1.7 NSES: A (5-8) #1 2061 6E (6-8) #5
7. Nitrogen: The Effects from Proper-ties versus Amount	Nitrogen, like other substances, can have an effect on life because of its unique properties and because of the amount of it in the environment, which contributes to air pressure necessary for life functions.	How do the properties of nitrogen and its amount in the atmosphere affect life on Earth?	• Students will explain how nitrogen's properties affect life on Earth • Students will explain how the amount of nitrogen in the atmosphere affects life on Earth. • Students will explain the difference between effects due to the properties of a gas and effects due to the amount of a gas.	**Addresses:** 2061: 4D (6-8) #6 NSES: B (5-8) #1.2 ISTE: 3,5
8. Atmo-spheric Science Conclu-sion: Sum-marizing Learning	The atmosphere is an important part of the Earth's system, which is composed of several gases that interact with the astronomical, geological, and biological characteristics of Earth's system through chemical reactions to maintain habitable conditions for humans.	How is the Earth's atmosphere im-portant to the Earth system, especially as it supports habitability to humans?	• Students will draw and explain concept maps that show how the gases in the atmosphere interact with many different systems to support human habitability. • Students will write a superhero comic book explaining how superheroes representing elements combine their powers to protect the Earth's habitability.	**Addresses:** 2061: 4B (6-8) #2 2061: 11A (3-5) #1 2061: 11A (3-5) #2 2061: 11A (6-8) #2 2061: 11A (6-8) #3 NSES: D (5-8) #1.8
9. Atmo-spheric Science Mission	Scientists use methods such as spectroscopy and instruments such as a spectrograph, thermometer, and barometer to collect data from a planet. Scientists then interpret this data to help answer a scientific question such as whether the planet has the necessary atmospheric conditions to support human habitability.	How do scien-tists go about investigating whether a planet has the necessary atmospheric conditions for human habit-ability?	• Students make predictions as to whether the atmospheres on Mars and Venus can support human habitability. • Students make observations, compare data, and reach conclusions regarding the atmospheric pressure, temperature, and composition on Mars and Venus. • Students identify the types of instruments that scientists use to gather data on the atmosphere of other planets. • Students identify the type of data scientists gather with these instruments.	**Addresses:** 2061: 1B (6-8) #1, 2 NSES: A (5-8) #1, 2 ISTE: (5-8) #3, 5, 6

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 further challenging.

The Five "E's"

The Astro-Venture Atmospheric Science Educator Guide intends 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 drawing 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 educators to Misconceptions, educators will try to bring out these misconceptions with their students and help their students to address them. 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 sometimes are asked to 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. In some cases, rubrics are provided for evaluation of this learning. In addition, students discuss and summarize the main concepts of the lesson, which are 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
Some 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/he 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.

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

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 Astro-Venture Astronomy 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/her hypothesis on 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

6-8

#1. Scientists differ greatly in what phenomena they study and how they go about their work. Although there is no fixed set of steps that all scientists follow, scientific investigations usually involve the collection of relevant evidence, the use of logical reasoning, and the application of imagination in devising hypotheses and explanations to make sense of the collected evidence.

#2. If more than one variable changes at the same time in an experiment, the outcome of the experiment may not be clearly attributable to any one of the variables. It may not always be possible to prevent outside variables from influencing the outcome of an investigation (or even to identify all of the variables), but collaboration among investigators can often lead to research designs that are able to deal with such situations.

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

6-8

#2. 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.

C. Processes That Shape the Earth

D. Structure of Matter

3-5

#4 When a new material is made by combining two or more materials, it has properties that are different from the original materials. For that reason, a lot of different materials can be made from a small number of basic kinds of materials.

6-8

#1 All matter is made up of atoms, which are far too small to see directly through a microscope. The atoms of any element are alike but are different from atoms of other elements. Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

#6 There are groups of elements that have similar properties, including…highly reactive nonmetals (such as chlorine, fluorine and oxygen), and some almost completely nonreactive gases (such as helium and neon) …An especially important kind of reaction between substances involves combination of oxygen with something else--as in burning or rusting.

#7 No matter how substances within a closed system interact with one another, or how they combine or break apart, the total weight of the system remains the same. The idea of atoms explains the conservation of matter: If the number of atoms stays the same no matter how they are rearranged, then their total mass stays the same.

E. Energy Transformations

6-8

#3 Heat can be transferred through materials by the collisions of atoms or across space by radiation.

F. Motion

G. Forces of Nature

5 The Living Environment

A. Diversity of Life

B. Heredity

C. Cells

6-8

#3 Within cells, many of the basic functions of organisms--such as extracting energy from food and getting rid of waste--are carried out.

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

6-8

#5 The environment may contain dangerous levels of substances that are harmful to human beings. Therefore, the good health of individuals requires monitoring the soil, air and water and taking steps to keep them safe.

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 & Energy and Time & 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

3-5

#1 In something that consists of many parts, the parts usually influence on another.

#2 Something may not work as well (or at all) if a part of it is missing, broken, worn out, mismatched or misconnected.

6-8

#2 Thinking about things as systems means looking for how every part relates to others. The output from one part of a system (which can include material, energy, or information) can become the input to other parts. Such feedback can serve to control what goes on in the system as a whole.

#3 Any system is usually connected to other systems, both internally and externally. Thus a system may be thought of as containing subsystems and as being a subsystem of a larger system.

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

A1. Abilities necessary to do scientific inquiry
A2. 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
   - #1.1 A mixture of substances often can be separated into the original substances.
   - #1.2 Substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties. In chemical reactions, the total mass is conserved. Substances often are placed in categories or groups if they react in similar ways; metals is an example of such a group.
   - #1.3 Chemical elements do not break down during normal laboratory reactions involving such treatments as heating, exposure to electric current, or reaction with acids. There are more than 100 known elements that combine in a multitude of ways to produce compounds, which account for the living and nonliving substances that we encounter.
2. Motions and forces
3. Transfer of energy
   - #3.1 Energy is a property of many substances and is associated with heat, light, electricity, mechanical motion, sound, nuclei, and the nature of a chemical. Energy is transferred in many ways.
   - #3.2 Heat moves in predictable ways, flowing from warmer objects to cooler ones, until both reach the same temperature.
   - #3.5 In most chemical and nuclear reactions, energy is transferred into or out of a system.
   - #3.6 The sun's energy arrives as light with a range of wavelengths consisting of visible light, infrared and ultraviolet radiation.

9-12

1. Structure of atoms
   #1.1 Matter is made of minute particles called atoms…
2. Structure and properties of matter
   #2.2 An element is composed of a single type of atom…
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
   #1.3 Cells carry on the many functions needed to sustain life. They grow and divide, thereby producing more cells. This requires that they take in nutrients, which they use to provide energy for the work that cells do and to make the materials that a cell or an organism needs.

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
   #1.8 The atmosphere is a mixture of nitrogen, oxygen and trace gases that include water vapor.

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
   #1.7 Natural environments may contain substances (for example, radon and lead) that are harmful to human beings. Maintaining environmental health involves establishing or monitoring quality standards related to use of soil, water and air.

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 system.
   - 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.