

National Aeronautics and Space Administration



Living and Working in Space: Habitat Teacher's Guide

GRADE LEVEL: 5 to 12

SUBJECT: Life Science, Earth Science, and Technology

Living and Working in Space: Habitat



Essential Question: What kinds of habitats can be designed to support extended human activity in space or on the moon or Mars?

Introduction

Humans have basic needs for food, water, air, and shelter. Ecosystems within Earth's biosphere provide for these needs. As we continue exploring space, and plan expeditions to other planets, the National Aeronautics and Space Administration is developing ways to support living away from Earth for long periods of time. The International Space Station, space shuttles, and space suits are habitats designed to meet basic human needs. NASA is developing and testing other systems to meet the needs of humans living in space or on the moon and Mars.

Living and Working in Space: **Habitat** is a problem-based learning activity. Guided inquiry prepares students to answer the Essential Question, "What kinds of habitats can be designed to support extended human activity in space or on the moon or Mars?" The final problem requires students to propose and defend a design for a research habitat on the moon or Mars for six people. To prepare for this final problem, students explore ecosystems, human nutrition, fitness, recycling of air and water, and waste removal. Students meet curriculum goals in the exciting context of human space exploration. Students extend their understanding of basic concepts by learning about space shuttles and the space station as habitats. The students' design and their explanation of the research habitat on the moon or Mars may be used to evaluate student understandings.

Objectives

1. Students discover and demonstrate conditions necessary for successful ecosystems using data from investigations of plant growth variables and simple, closed ecosystems.
2. Students demonstrate understanding of proper nutrition and exercise by developing and explaining a diet and exercise plan to support healthy human activity in a habitat on the moon or Mars.
3. Students demonstrate understanding of chemical cycles (CO_2 , O_2 , H_2O) in ecosystems by proposing and defending a design for maintaining clean water and breathable air for six humans in a habitat on the moon or Mars.
4. Students demonstrate understanding of the recycling of matter in an ecosystem by designing and explaining methods for handling waste in a habitat for six humans on the moon or Mars.
5. Students demonstrate understanding of ecosystems that could support humans in extraterrestrial environments by designing and explaining the design of a habitat for extended human activity on the moon or Mars.

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Overview

*Living and Working in Space: **Habitat*** is divided into an engagement activity and four content areas. The engagement is called The Sealed Room and introduces the problem students will solve. The content areas are: Life in a Sealed Container, Healthy Choices, Air and Water, and Trash or Treasure. Each content area has guide questions to focus the investigations.

- Life in a Sealed Container: What are the important characteristics of a successful ecosystem on Earth? What modifications are necessary for a successful ecosystem on the moon or Mars?
- Healthy Choices: How can humans maintain proper nutrition and exercise? What modifications are necessary for extended space missions?
- Air and Water: How can humans maintain sufficient clean water and breathable air? What modifications are necessary for extended space missions?
- Trash or Treasure: How can matter be recycled effectively? What modifications are necessary for extended space missions?

Guide questions can be used for formative assessment. Each content area contains multiple investigations and readings. Tasks and rubrics for assessment are available online.

*All teacher resources, assessment rubrics and student assignments can be downloaded or linked from the pages of the Living and Working in Space: **Habitat**. In addition, the “Related Links” at the bottom of the home page contains links to information about the space station, moon and Mars, that is important for all content areas.*

Within each content area students will:

1. Learn background knowledge (e.g., learn about the Food Guide Pyramid, caloric requirements, etc).
2. Discover how the first part of the guide question is answered within an Earth environment (e.g., students develop a nutritional menu for themselves for a week and identify sources of food).
3. Read about and do activities that lead to an understanding of solutions developed for the space station or shuttle (e.g., students research shuttle and space station menus and develop a menu for a week of shuttle operation and for week #12 on the space station).
4. Research resources for and challenges of solving the problem on moon or Mars.
5. Propose a preliminary moon or Mars solution. (The solution to the final design problem requires solutions from several of the content areas.)

A description of the content of the engagement activity along with the four content areas of Living and Working in Space: **Habitat** follows. This brief overview is intended to help you align Living and Working in Space: **Habitat** with your curricular goals. You may wish to modify or omit content areas to meet your needs. Please realize, however, that the students will be able to create the most complete solutions to the Essential Question if they investigate each content area.

The Sealed Room (20-30 minutes): This engagement activity and introduction of the design problem is essential. The engagement activity will set the stage for subsequent investigations and identify knowledge gaps and misconceptions. You should do The Sealed Room activity with your students even if you choose to omit one or more of the content areas.

Life in a Sealed Container (variable time requirement – students make observations of

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ecosystems over several weeks): Students experiment with combinations of biotic (living) and abiotic (non-living) elements in closed and sealed containers to discover the requirements for a successful ecosystem. Other investigations with different soils or hydroponics reveal requirements for plant growth. Articles about NASA research show students current technology. As an assessment students can participate in NASA's plant growth chamber design challenge. Students may also design experiments to test growth characteristics of seeds flown in space, if they are available. Student design of sealed ecosystems and explanation of results can provide formative assessment.

Healthy Choices (variable time requirement): Students learn how to determine their caloric needs, read food labels and use the Food Guide Pyramid to develop healthy menus for themselves. A fitness challenge allows students to participate in fitness programs developed with the exercise trainers for the astronauts. Special articles describe the procedures, foods and menus prepared for astronauts. Student design of a diet and fitness plan for an extended stay on the moon or Mars can provide formative assessment.

Air and Water (variable time requirement): Students learn about chemical cycles (CO_2 , O_2 , H_2O) in Earth ecosystems and the need for protecting water supplies and clean air. Articles describe life support systems developed by NASA to provide breathable air and clean water. Activities allow students to investigate ways to purify water and provide breathable air. The design of a life support system for the moon or Mars can provide a formative assessment.

Trash or Treasure (variable time requirement): Students learn about recycling matter and explore creative solutions demanded for long-term space exploration. Students first learn how matter is recycled in ecosystems. Recycling of biological waste is tied to Life in a Sealed Container. Students extend their study to include the efforts needed in an industrial society to recycle matter. Investigations of home and school waste lead to a greater awareness of the need for recycling manufactured materials. Articles describing new technology developed for the space program extend student understanding. The design of a recycling system for an extended stay on the moon or Mars can provide a formative assessment.

Suggestions for Use

Living and Working in Space: **Habitat** is modular to provide flexibility. The core concepts are generally found in a life science class. However, Living and Working in Space: **Habitat** could be used in a technology class by placing heavier emphasis on engineering design. The content areas Air and Water and Trash or Treasure and the soil activities in Life in a Sealed Container are appropriate in an Earth science class.

Living and Working in Space: **Habitat** is designed so that you can easily modify it to fit your curriculum needs. For example, if your life science course doesn't include nutrition and exercise, don't include Healthy Choices. Also, in each content area there are multiple learning experiences – you can assign all or just some. Some of the resources contain similar information or activities. For example, in Healthy Choices, *Food and Fitness* and *The Science of Energy Balance* teach similar concepts. You will have to decide which is more appropriate.

While Living and Working in Space: **Habitat** is designed to provide flexibility, there are three strong recommendations.

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1. Living and Working in Space: **Habitat** is designed to promote inquiry. Establish an environment that encourages discovery, questioning, thinking and explaining. (See The Inquiry Process
http://www.nasa.gov/audience/foreducators/son/about/F_SON_Resource_Inquiry.html and Unique Assignments to Promote Inquiry
http://www.nasa.gov/audience/foreducators/son/about/F_SON_Resource_Assignments.html
2. Regardless of modifications you choose to make, this module is most effective if you use The Sealed Room activity to begin. This establishes the exciting context of space exploration and reveals knowledge gaps.
3. Organize learning experiences so that students progress from the more concrete and factual to open-ended problem solving. Students should
 - Learn the background knowledge first.
 - Discover how the problem is solved within an Earth environment.
 - Read about and do activities that lead to an understanding of solutions developed for the space station or shuttle.
 - Research resources for and challenges of solving the problem on moon or Mars.
 - Propose a preliminary moon or Mars solution.

Hint for pacing For a life science class Life in a Sealed Container explores the core content. Many of the activities in this content area need a day to set up the investigation followed by several days or even several weeks of observation. If you begin student investigations with the activities in Life in a Sealed Container, they can spend a few minutes each day making observations on long term investigations and then do activities in Healthy Choices, Air and Water, and Trash or Treasure.

Extension Obviously any habitat needs energy. *Solar Energy for Space Exploration* http://www.nasa.gov/audience/foreducators/son/energy/F_Solar_Energy_2column.html is a problem-based inquiry activity that challenges students to design a solar energy system to support a research habitat on the moon or Mars. *Solar Energy for Space Exploration* is part of the Student Observation Network module, Living and Working in Space: **Energy**. Living and Working in Space: **Habitat** and *Solar Energy for Space Exploration* could be used together as the life science and physical science parts of an integrated science course.

Background

An ecosystem is a community of interacting biotic (living) and abiotic (non-living) elements, transferring energy and recycling material. Ecosystems vary greatly in size. An ecosystem could be a desert covering several states or a small pond. The Earth could be considered a huge ecosystem with the biosphere (living organisms), atmosphere, hydrosphere (all water except water in atmosphere), and geosphere (soil and upper part of crust) interacting.

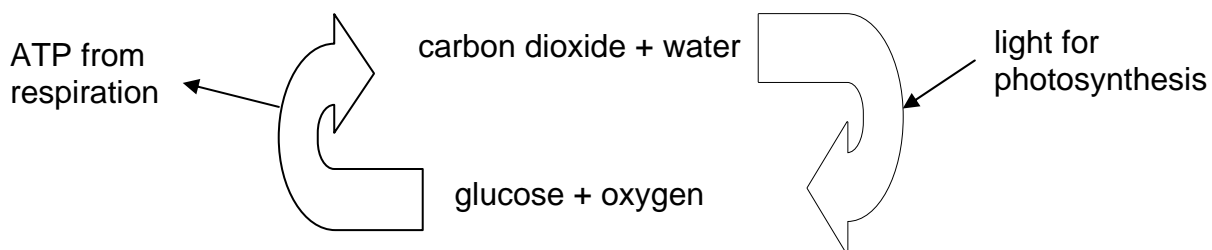
Energy for ecosystems can come from a variety of sources. For example, ecosystems deep in the ocean can be fueled by chemical rather than light energy. However, the energy source for Earth's ecosystems is most often light from the Sun. Light energy drives photosynthesis in plants, algae, and some bacteria. During photosynthesis carbon dioxide and water are converted into glucose and oxygen. Plants use the glucose for energy and for the building blocks of proteins and carbohydrates that make up the body of the plant. When plants are eaten glucose, proteins and carbohydrates are transferred to animals (herbivores or omnivores) that use these chemicals for energy and building blocks. When a plant dies, these chemicals are transferred to decomposers for energy and building materials. The transfer of energy in ecosystems defines the energy

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pyramid. Energy is provided to producers (e.g. plants) that are eaten by primary consumers (herbivores). Primary consumers are eaten by secondary consumers, and so on. All the producers in an ecosystem are at the bottom of the energy pyramid. The next level up represents energy available for the primary consumers. The level above that represents energy available for the secondary consumers. At each level useful energy is lost from the ecosystem, ultimately as heat from the organisms' life processes. Energy is not destroyed. Energy is transformed to types of energy not useful to organisms in the ecosystem. It is calculated that an average of 90% of the energy at each level of the energy pyramid is converted to non-usable energy. Only 10% is passed 'up' to the next level.

Matter is also passed from producer to primary consumer and from primary consumer to secondary consumer. Matter is recycled within the ecosystem. Even the waste from one organism provides essential material for other organisms. There are four important cycles in Earth ecosystems: the carbon cycle, the nitrogen cycle, the phosphorous cycle, and the water cycle. Oxygen is an important element in Earth ecosystems. While it is involved in all four cycles, we generally consider oxygen recycled as part of the carbon cycle.

The carbon cycle begins with atmospheric carbon dioxide. During photosynthesis producers convert atmospheric carbon dioxide and water into glucose and oxygen. Plants, as well as animals, use glucose in respiration to provide energy. Respiration combines glucose and oxygen to produce high-energy molecules (ATP) and carbon dioxide and water as waste. In its simplest form the carbon cycle looks like this:



This is, of course, an oversimplification. Glucose molecules are also used as building blocks for the body of the producer. A common misconception is that plants, a tree for example, gets the material for its trunk, roots and leaves from the soil. In fact, almost all of the tree mass comes from atmospheric carbon dioxide and water. When a plant dies and is decomposed or when a plant is eaten by a consumer, the carbon is involved in many, complex reactions.

Nitrogen is an essential element for many biological chemicals including amino acids for protein. Although nitrogen gas is 78% of the atmosphere, very few organisms can use nitrogen gas. Special groups of bacteria convert nitrogen from the atmosphere into nitrogen compounds in the soil that plants can use. Decomposers convert nitrogen wastes and dead organic matter into usable forms for plants or back to atmospheric nitrogen.

Phosphorous is critical for several important biological chemicals, especially for DNA and the energy molecule, ATP. Rock containing phosphorous erodes making phosphorous available to plants. Decomposers release phosphorous back into the soil from wastes and dead organic matter.

The cycling of water occurs through evaporation, transpiration, condensation, and precipitation. The Sun powers evaporation, especially from large bodies of water, and transpiration from plants.

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Water carried into the atmosphere condenses and falls as rain and snow. Water can follow a very short cycle from oceans or lakes to the atmosphere and back as precipitation. Water can also follow a much longer cycle including plants, animals, soil, rivers, glaciers, ground water, and the atmosphere.

Healthy ecosystems use resources and produce materials sustainably. That means that no population uses resources more quickly than the resources can be replaced by other parts of the ecosystem. In addition, no population produces waste more quickly than the waste can be used and recycled by other parts of the ecosystem. *Living and Working in Space: Habitat* provides excellent opportunities for students to learn about sustainability in ecosystems and how to promote sustainability.

A successful ecosystem needs a source of energy and enough complexity to recycle material. Successful ecosystems can be designed in sealed containers. Light supplies energy for producers and drives a simple water cycle. Air can supply carbon dioxide, and nutrients in water can supply nitrogen and phosphorous while decomposers recycle material. Activities in *Living and Working in Space: Habitat* allows students to discover what is critical for a successful ecosystem by designing their own ecosystems in sealed containers.

The International Space Station is a designed ecosystem, but it does not rely solely on biological solutions to maintain requirements for long-term human occupation. For one thing, it is not a closed ecosystem. Significant amounts of material are brought into and taken out of the system. Food and water are supplied on a regular basis. Trash is removed by the shuttle or the Russian Progress vehicles. Physical-chemical systems are used to clean the air and water. Carbon dioxide is removed from the air, and oxygen is replenished. Water is recycled. Resources within this module provide information about technologies being used on the space station.

Long-term research outposts on the moon or Mars will require more recycling of material. It will be too expensive to re-supply food and water. Growing plants for food in lunar or Martian habitats makes sense at many levels. As plants grow they remove carbon dioxide and replenish oxygen. Decomposers in soil or hydroponics systems can recycle biological waste and provide nutrients for more plant growth. Plants do a good job of purifying water. Researchers are developing biological systems that will allow long-term human habitation in a sealed container. Researchers are also developing improved physical-chemical systems. New packaging materials are also being developed that can go into space and be recycled.

It is unlikely that researchers in lunar or Martian habitats will be growing plants to feed animals to provide meat in their diet. It is quite likely that researchers will be vegetarians. The energy pyramid explains why. On average only about 10% of the energy is passed 'upward' in the pyramid. If a human eats grain, the human gets about 10% of the energy from the grain. If a chicken eats the grain and only gets 10% of the energy from the grain, and if a human eating the chicken only gets 10% of the energy from the chicken, then 10 times as much grain needs to be grown. In addition the chicken requires water, air and space. NASA is developing lists of appropriate crops for space exploration and menus for nutritious and interesting foods from this crop list.

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National Science Education Standards

Grades 5-8 (Core Understandings)

- Content Standard C (Life Science): Populations and Ecosystems #3 “For ecosystems, the major source of energy is sunlight. Energy entering ecosystems as sunlight is transferred by producers into chemical energy through photosynthesis. That energy then passes from organism to organism in food webs.”
- Content Standard C (Life Science): Populations and Ecosystems #4 “The number of organisms an ecosystem can support depends on the resources available and abiotic factors, such as quantity of light and water, range of temperatures, and soil composition. Given adequate biotic and abiotic resources and no disease or predators, populations (including humans) increase at rapid rates. Lack of resources and other factors, such as predation and climate, limit the growth of populations in specific niches in the ecosystem.”
- Content Standard F (Science in Personal and Social Perspectives): Personal Health #1 “Regular exercise is important to the maintenance and improvement of health. The benefits of physical fitness include maintaining healthy weight, having energy and strength for routine activities, good muscle tone, bone strength, strong heart/lung systems, and improved mental health. Personal exercise, especially developing cardiovascular endurance, is the foundation of physical fitness.”
- Content Standard F (Science in Personal and Social Perspectives): Personal Health #5 “Food provides energy and nutrients for growth and development. Nutrition requirements vary with body weight, age, sex, activity, and body functioning.”

Grades 9-12 (Core Understandings)

- Content Standard C (Life Science): Interdependence of Organisms #1 “The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.”
- Content Standard C (Life Science): Interdependence of Organisms #2 “Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.”
- Content Standard C (Life Science): Matter, Energy and Organization in Living Systems #5 “The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.”
- Content Standard C (Life Science): Matter, Energy and Organization in Living Systems #6 “As matter and energy flows through different levels of organization of living systems--cells, organs, organisms, communities--and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.”
- Content Standard F (Science in Personal and Social Perspectives): Environmental Quality #1 “Natural ecosystems provide an array of basic processes that affect humans. Those processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients. Humans are changing many of these basic processes, and the changes may be detrimental to humans.”