

# Lesson 1: Identifying Criteria and Constraints

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## Lesson Snapshot

*Packing  
Up for the  
Moon*

*Lesson 1  
Identifying  
Criteria and  
Constraints*

### Overview

**Big Idea:** Design is a creative planning process that leads to useful products and systems.

**Teacher's Note:** Big ideas should be made explicit to students by writing them on the board and/or reading them aloud.

**Purpose of Lesson:** This lesson prepares students to identify the requirements for the design and development of a plant growth chamber on the lunar surface.

**Lesson Duration:** Two hours.

### Activity Highlights

**Engagement:** The teacher asks students, working in pairs, to speculate on whether plants can grow on the moon.

**Exploration:** The teacher displays a plant or an image of a plant and asks students to list the conditions required for the plant's growth. Students identify the role of plants in our ecosystem. Students read *Moon ABCs Fact Sheet* and answer selected questions.

**Explanation:** The students view *Into The Cosmos*. The teacher describes the benefits of growing plants in space for astronauts on extended missions. The teacher describes characteristics of invention and innovation and how requirements affect design.

**Extension:** Students, working in design teams of two to four, identify criteria and constraints for a plant growth chamber to be used on the moon.

**Evaluation:** Student knowledge, skills and attitudes are assessed using brief constructed response items and selected response items as well as optional rubrics for class participation.

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### Lesson Duration

- Two hours.

### Standards/Benchmarks

*Technology: Standards for Technological Literacy (STL) (ITEA, 2000/2002)*

- Students will develop an understanding of the attributes of design. (ITEA/STL 8)
  - Design is a creative planning process that leads to useful products and systems. (ITEA/STL 8E)
  - There is no perfect design. (ITEA/STL 8F)
  - Requirements for a design are made up of criteria and constraints. (ITEA/STL 8G)
- Students will develop an understanding of engineering design. (ITEA/STL 9)
  - Brainstorming is a group problem-solving design process in which each person in the group presents his or her ideas in an open forum. (ITEA/STL 9G)
- Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation and experimentation in problem solving. (ITEA/STL 10)
  - Invention is a process of turning ideas and imagination into devices and systems. Innovation is the process of modifying an existing product or system to improve it. (ITEA/STL 10G)
- Students will develop the abilities to apply the design process. (ITEA/STL 11)
  - Specify criteria and constraint for the design. (ITEA/STL 11I)

*Science: Benchmarks for Science Literacy (AAAS, 1993)*

- The Nature of Technology/Technology and Science (AAAS 3A)
  - Engineers, architects and others who engage in design and technology use scientific knowledge to solve practical problems, but they usually have to take human values and limitations into account as well. (AAAS-3A)
- The Physical Setting/The Earth (AAAS 4B)
  - The moon's orbit around the earth once in about 28 days changes what part of the moon is lighted by the sun and how much of that part can be seen from the earth-the phases of the moon. (AAAS-4B)
- The Living Environment/Flow of Matter and Energy (AAAS 5E)
  - Energy can change from one form to another in living things. Animals get energy from oxidizing their food, releasing some of its energy as heat. Almost all food energy comes originally from sunlight. (AAAS-5E)
- The Human Organism/Basic Functions (AAAS 6C)
  - To burn food for the release of energy stored in it, oxygen must be supplied to cells and carbon dioxide removed. Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced. (AAAS- 6C)

*Mathematics: Principles and Standards for School Mathematics (NCTM, 2000)*

- Representation
  - Use representations to model and interpret physical, social and mathematical phenomena.
- Measurement
  - Solve problems involving scale factors, using ratio and proportion.

**Learning Objectives**

Students will:

1. Explain how invention and innovation relate to the development of new products, processes and systems.
2. Identify criteria and constraints related to the design and development of a plant growth chamber on the lunar surface.
3. Explain that requirements for a design are made up of criteria and constraints.
4. Explain why there is no perfect design.
5. Explain that an organism uses oxygen to burn food to release energy and that the energy was originally from sunlight.
6. Identify the four main goals in the Vision for Space Exploration.
7. Determine the approximate ratio of two areas.

**Student Assessment Tools and/or Methods**

1. Selected Response Items

T	<b>F</b>	1.	Criteria are drawings used to represent the solution to a design challenge.
<b>T</b>	F	2.	Constraints are limits related to the design of a technology system.
T	<b>F</b>	3.	Plants convert oxygen to carbon dioxide through a process called transpiration.
<b>T</b>	F	4.	Requirements are made up of criteria and constraints.
T	<b>F</b>	5.	A design can be perfect if tested and refined thoroughly.
<b>T</b>	F	6.	Plants produce more food and oxygen when the light intensity is increased.
<b>T</b>	F	7.	The Vision for Space Exploration includes returning humans to the moon.
T	<b>F</b>	8.	Invention is the improvement of an existing system.
T	<b>F</b>	9.	The heart takes in oxygen for the combustion of food and eliminates the carbon dioxide produced.
<b>T</b>	F	10.	Energy can change from one form to another in living things.

## 2. Optional Rubric for Class Participation

*Teacher's Note:* Teachers may choose to use this rubric as a way to assess students, with or without making it a basis for student grades.

Category	Below Target	At Target	Above Target
<b>Preparation</b>	Rarely prepared. Minimal effort to participate.	Prepared for class. Attempts to answer teacher-generated questions.	Well prepared for class. Attempts to answer teacher-generated questions and adds additional information to class when relevant.
<b>Curiosity</b>	Rarely demonstrates curiosity.	Usually demonstrates curiosity.	Consistently demonstrates curiosity.
<b>Motivation for Learning</b>	Rarely demonstrates motivation for learning.	Usually demonstrates motivation for learning.	Consistently demonstrates motivation for learning.
<b>Use of Time</b>	Gives up easily; is not engaged. Has difficulty remaining on task.	Makes good use of class time to work on assignments and projects.	Makes excellent use of class time to work on assignments and projects.

## 3. Rubric for Brief Constructed Response Item

Explain how astronauts would benefit by having a small lunar plant growth chamber on an extended (3 month +) expedition on the moon's surface.

Category	Below Target	At Target	Above Target
<b>Understanding</b>	Response demonstrates an implied, partial or superficial understanding of the question.	Response demonstrates an understanding of the question.	Response demonstrates an understanding of the complexities of the concept.
<b>Focus</b>	Lacks transitional information to show the relationship of the support to the question.	Addresses the demands of the question.	Exceeds the demands of the question.
<b>Use of Related Information</b>	Uses minimal information from the lesson to clarify or extend meaning.	Uses some expressed or implied information from the lesson to clarify or extend meaning.	Effectively uses expressed or implied information from the lesson to clarify or extend meaning.

## Resource Materials

### Print Materials

1. *Teachers and students investigating plants in space: A teacher's guide with activities for life sciences* (EG-1997-02-113-HQ). (1997). ASIN: B000H48XM6. Retrieved July 6, 2007 from <http://education.nasa.gov/edprograms/core/home/index.html>
2. *Fundamentals of space biology: research on cells, animals and plants in space* New York: Springer.
3. Pierce, A. & Karwatka, D. (1999). *Introduction to technology*. New York: Glencoe/McGraw-Hill, (pp. 157-180).

### Audiovisual Materials

1. *NASA connect - functions and statistics - International Space Station - Up to us*. (n.d.). Retrieved July 6, 2007 from <http://www.open-video.org/details.php?videoid=6311>
2. *JFK moon speech at Rice University*. (1962, November 12). Retrieved from <http://www1.jsc.nasa.gov/er/seh/ricetalk.htm>

### Internet Sites

1. *Into the cosmos*. (n.d.) Retrieved July 6, 2007 from <http://www.nasa.gov/multimedia/video-gallery/index.html>
2. *Exploring the moon: A teacher's guide with activities* (pp. 17-18). (1997). Retrieved on July 6, 2007 from <http://ares.jsc.nasa.gov/Education/Activities/ExpMoon/MoonFactSheet.pdf>
3. *Educational plant growth hardware* (Space Garden and BPSe). (n.d.). Retrieved July 6, 2007 from <http://www.orbitec.com/outreach/index.htm>
4. *Space agriculture in the classroom* (n.d.). Retrieved July 6, 2007 from <http://www.spaceag.org/>

## Lesson 1: Modified 5-E Lesson Plan

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### Engagement

*Teacher's Note:* See **Enrichment** below for an opportunity to enhance the **Engagement** if time allows.

1. The teacher shows the students a picture or pictures of the moon.
2. The teacher asks the students, working in pairs, to speculate on whether plants can grow on the moon.
3. The teacher solicits brief responses from students and points out that most answers begin with “Yes, if” or “No, because.”

### Exploration

1. The teacher displays a plant or an image of a plant that grows in the local Earth environment and then asks students to list the conditions required for the plant's growth.
2. The teacher asks students to work with their neighbors to make a list of the roles that plants play in Earth's ecosystem.
3. Students read *Moon ABCs Fact Sheet* and record brief answers to each question.
4. Students report on the requirements for growing plants on the moon.

### Explanation

1. The teacher facilitates a discussion of the requirements for plant growth on the moon. The teacher asks students:
  - What would we need to “bring along”?
1. The teacher shows the video clip, *Into the Cosmos* (See References page 29).
  - Prior to viewing, the teacher explains that the speech was given on January 14, 2004 during the investigation of the Space Shuttle Columbia disaster.
  - After viewing the video clip, the teacher asks students to identify the four main goals in the Vision for Space Exploration.
    1. Return the space shuttle to regular service.
    2. Complete the International Space Station by 2010.
    3. Develop and use the Crew Exploration Vehicle to return humans to the moon.
    4. Explore Mars and beyond.
3. The teacher explains that astronauts on extended missions could benefit by having live plants with them to:
  - Provide food.
  - Provide oxygen.
  - Purify water.
  - Provide a psychological lift—provide “sense of home.”
4. The teacher explains how food and energy provided by plants provide energy for astronauts.
  - Energy can change from one form to another in living things.
  - Animals get energy from oxidizing their food, releasing some of the energy as heat.
  - To burn food for the release of energy stored in it, oxygen must be supplied to cells and carbon dioxide removed.
  - Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced.

5. The teacher explains that requirements are made up of criteria and constraints.
  - *Criteria* are specific outcomes for a project. “What do you want it to do?” and “How well do you want it to be done?”
  - *Constraints* are limits. These are based on the resources available (time, tools and machines, materials, capital, people, information, energy and time) and the environment in which the solution must exist.
6. The teacher explains that there is no perfect design. Different solutions may satisfactorily solve a problem, but no one solution is perfect. The best designs optimize the desired qualities—safety, reliability, economy and efficiency—within the given constraints.
7. The teacher explains that invention and innovation relate to the development of new products, processes and systems.
  - Invention is the creation of a new system.
  - Innovation is the improvement of an existing system.
  - Both invention and innovation require creativity and perseverance.
  - Both invention and innovation serve the purpose of satisfying the needs and wants of people, society and industry.

### Extension

*Teacher’s Note:* See **Enrichment** below for a way to enhance the **Extension**, if time allows.

1. In groups of two or four, students form design teams.
2. The design teams use *Understanding the Role of Plants in a Lunar Base* to examine and identify criteria for a lunar plant growth chamber.

### Evaluation

Student knowledge, skills and attitudes are assessed using selected response items and rubrics for class participation, brief constructed responses and the oral presentation. The rubrics are presented in advance of the activities to familiarize students with the expectations and performance criteria. They are also reviewed during the activities to guide students in completing assignments. The teacher may wish to develop a collection of annotated exemplars of student work based on the rubrics. The exemplars serve as benchmarks for future assessments and may be used to familiarize students with the criteria for assessment.

### Enrichment

The teacher may choose to use the following activities to enhance and extend the lesson. Activity 1 may be used as a warm-up to Lesson 1 as a whole by using it as **Engagement** or Activity 1 may be used as an introduction to the **Extension** portion of Lesson 1.

1. The teacher asks students to write their thoughts about the following:
  - What portion of the student body of this school are boys?
  - What are some different ways we could express our answer?

The teacher asks students to share their ideas and discuss the different ways the answers could be expressed. The teacher asks students to think about and write an answer for the following:

- How could we use data from this class to estimate the number of boys in the school?

The teacher asks students to share their ideas and solutions.

2. The teacher examines the International Space Station using the NASA Connect Video – Functions and Statistics: International Space Station (<http://www.open-video.org/details.php?videoid=6311>). Then, the teacher prints the educator’s guide from [http://connect.larc.nasa.gov/connect\\_bak/pdf/00\\_5.pdf](http://connect.larc.nasa.gov/connect_bak/pdf/00_5.pdf) and makes copies of the student cue cards (pg 14). The following video time segments may be used in class to discuss and answer questions regarding the construction and use of the space station: 0:00–11:00 and 18:35–28:30.
3. The teacher shows students the video clip “JFK Moon Speech at Rice University, 11/12/62” from <http://www1.jsc.nasa.gov/er/seh/ricetalk.htm>. The teacher leads students in a discussion that compares and contrasts the messages, missions and settings between this and the [Into The Cosmos](#) speech by George Bush.



## Lesson 1: Lesson Preparation

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### Teacher Planning

The laboratory-classroom should provide a flexible, resource-rich learning environment that includes areas for lectures and demonstrations, small group meetings and research activities. The teacher adapts the learning environment based on the requirements of the unit or lesson. For this lesson, areas for lecture and demonstration, design, small group meetings and fabrication activities should be readied.

### Tools/Materials/Equipment

- Chalk board
- Teacher rubric included in lesson.
- Copies of *Moon ABCs Fact Sheet* (one per pair of students)
- Copies of *Understanding the Role of Plants in a Lunar Base* (one per pair of students)
- Overhead projector
- Computer with Internet access, LCD projector and speakers
- Graph paper

### Classroom Safety and Conduct

1. Students demonstrate respect and courtesy for the ideas expressed by others in the class.
2. Students show respect and appreciation for the efforts of others.
3. Students use tools and equipment in a safe manner and assume responsibility for their safety as well as for the safety of others.

## Moon ABCs Fact Sheet

Property	Earth	Moon	Brain Busters
Equatorial Diameter	12,756 km	3,476 km	How long would it take to drive around the Moon's equator at 80 km per hour?
Surface Area	510 million square km	37.8 million square km	The Moon's surface area is similar to that of one of Earth's continents. Which one?
Mass	$5.98 \times 10^{24}$ kg	$7.35 \times 10^{22}$ kg	What percentage of Earth's mass is the Moon's mass?
Volume	—	—	Can you calculate the volumes of Earth and the Moon?
Density	5.52 grams per cubic cm	3.34 grams per cubic cm	Check this by calculating the density from the mass and volume.
Surface Gravity	9.8 m/sec/sec	1.63 m/sec/sec	What fraction of Earth's gravity is the Moon's gravity?
Crust	Silicate rocks. Continents dominated by granites. Ocean crust dominated by basalt.	Silicate rocks. Highlands dominated by feldspar-rich rocks and maria by basalt.	What portion of each body is crust?
Mantle	Silicate rocks dominated by minerals containing iron and magnesium.	Similar to Earth.	Collect some silicate rocks and determine the density. Is the density greater or less than the Earth/Moon's density? Why?

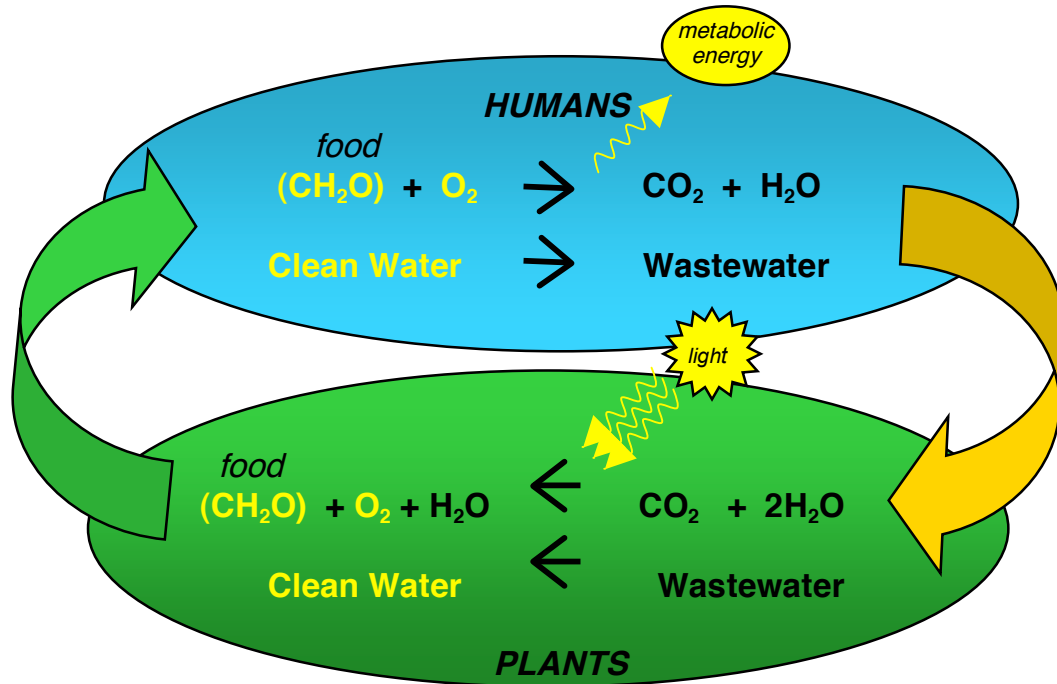
Continued

## Moon ABCs Fact Sheet

Property	Earth	Moon	Brain Busters
Core	Iron, nickel metal	Same, but core is much smaller	What portion of each body is core?
Sediment or Regolith	Silicon and oxygen bound in minerals that contain water, plus organic materials.	Silicon and oxygen bound in minerals, glass produced by meteorite impacts, small amounts of gases (e.g., hydrogen) implanted by the solar wind. No water or organic materials.	Do you think life ever existed on the Moon? Why or why not?
Atmosphere (main constituents)	78% nitrogen, 21% oxygen	Basically none. Some carbon gases (CO <sup>2</sup> , CO, and methane), but very little of them. Pressure is about one-trillionth of Earth's atmospheric pressure.	Could you breathe the lunar atmosphere?
Length of Day (side-real rotation period)	23.93 hours	27.3 Earth days	How long does daylight last on the Moon?
Surface Temperature	Air temperature ranges from -88 °C (winter in polar regions) to 58 °C (summer in tropical regions).	Surface temperature ranges from -193 °C (night in polar regions) to 111 °C (day in equatorial regions).	Why are the temperatures of Earth and the Moon so different?
Surface Features	25% land (seven continents) with varied terrain of mountains, plains, river valleys. Ocean floor characterized by mountains, plains, and trenches.	84% heavily-cratered highlands. 16% basalt-covered maria. Impact craters—some with bright rays, crater chains, and rilles.	Compare maps of Earth and the Moon. Is there any evidence that plate tectonics operated on the Moon?

## Understanding the Role of Plants in a Lunar Base

Through the process of *photosynthesis*, plants remove carbon dioxide, or  $\text{CO}_2$ , from the air, while producing oxygen, or  $\text{O}_2$  and food, shown as a generic unit of carbohydrate below. This entire process is the reverse of respiration for humans, where food and  $\text{O}_2$  sustain metabolic needs. Plant systems can also be used to help purify wastewater. Water evaporates from the leaves and resultant humidity can be condensed as a source of clean water. This process is called *transpiration*.



In space, plants will serve two main functions: oxygen production and food supply. A plant's ability to supply the oxygen needs for a person depends largely on the species of plant and the intensity and quality of light it receives.

At very high light intensities, wheat could supply much of one human's food and all their  $\text{O}_2$  needs from an area as small as 15 square meters.

At moderate light intensities, a diverse mix of crops could supply a more complete diet for one person from about 50 square meters and meet all of their  $\text{O}_2$  needs.

Use the information in *Understanding the Role of Plants in a Lunar Base* to complete the following:

1. Through photosynthesis, plants provide three important things to humans. They are \_\_\_\_\_, \_\_\_\_\_ and \_\_\_\_\_.
2. What happens during transpiration?
  - a. Water from the leaves is put into the atmosphere.
  - b. Water from the root flows to the stem.
  - c. Oxygen from the air is breathed by humans.
  - d. Wastewater is absorbed by roots.
3. What are the two main roles plants will serve in space?
4. What two factors affect a plant's ability to supply the oxygen needs for a person?
5. With high intensity lights, how much area would be needed for wheat to supply the food and oxygen needs for one person?
6. Explain why you think moderate lighting would require a larger growing area.

**Read and complete the following task.**

The teacher has drawn a square on the board that is one meter by one meter. This is an area of one squared meter. As a team, devise a plan for determining the following without the use of any measuring tools:

What portion of the classroom is taken up by 15 square meters?

Implement your plan and present your results in the form of a sketch of the classroom with the 15 square meters shaded in. Write a brief statement explaining how you arrived at your result.

**Identify Criteria for a Lunar Plant Growth Chamber.**

The first lunar bases will not likely be able to provide the large growing space needed to satisfy the food and oxygen needs of the astronauts. Instead, small plant growth chambers may be used to grow food for the purpose of supplementing the diet of the astronauts. Such a plant growth chamber would need to have systems that support plant life.

Make a list of criteria for such a plant growth chamber. Remember: Criteria are specific outcomes for a project. “What do you want it to do?” and “How well do you want it to be done?”

The Lunar Plant Growth Chamber must:

1. \_\_\_\_\_
2. \_\_\_\_\_
3. \_\_\_\_\_
4. \_\_\_\_\_
5. \_\_\_\_\_
6. \_\_\_\_\_

## Understanding the Roles of Plants in a Lunar Base

### Suggested Response Sheet

1. Remove carbon dioxide ( $\text{CO}_2$ ), produce oxygen ( $\text{O}_2$ ), and produce food.
2. a: Water from the leaves is put into the atmosphere.
3. Oxygen production and food supply.
4. The species of the plant and the intensity and quality of light it receives.
5. 15 square meters.
6. Answers will vary.