Title: Going Green on the Red Planet
Subject/Course: Life Science/Physical Science
Topic: Growing Plants in Space
Grade: 9-12
Time Needed: 50 minutes to watch video and discuss the subject
50 minutes for the experiment setup
Several weeks to collect data

Stage 1 – Desired Results

Established Goal(s)/Content Standard(s):
HS-LS1.C.1 (High School Life Sciences): The process of photosynthesis converts light energy to stored chemical energy by converting carbon dioxide plus water into sugars plus released oxygen.
HS-LS2.B.1 (High School Life Sciences): Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.
HS-PS3.D.2 (High School Life Sciences): The main way that solar energy is captured and stored on Earth is through the complex chemical process known as photosynthesis.
HS-PS3.D.3 (High School Physical Sciences): Solar cells are human-made devices that likewise capture the sun's energy and produce electrical energy.

Understanding (s)	Essential Question(s):
Students will understand that: ● Humans can't colonize Mars without food, and we won't be able to bring it with us. ● Living in space requires different technology. ● You must allow for weight restrictions, light restrictions and gravitational challenges.	● What do plants need to grow? ● Can all of these plant needs be met on a spacecraft or another planet? ● What are some of the challenges of providing for these needs? ● What kind of technologies could be developed to help plants grow in space? ● What kind of characteristics would an ideal space plant have? ● Where do plants get their energy? ● What kind of light is needed?

Student objectives (outcomes):
Students will be able to:
- Choose the best plant varieties
- Manipulate length and color of light sources for optimal growing conditions
- Construct a hydroponic garden
- Compare the difference between traditional growth in potting soil with sunlight versus hydroponic growth with LED lights

Stage 2 – Assessment Evidence

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Performance Task(s):

- Students will plant lettuce in hydroponic pots, grown under four different color LED lights: Red, Blue, Yellow and Green, and chart their progress over several weeks.
- Students will also plant the same variety of lettuce in regular potting soil in sunlight and chart the progress.
- They will then compare hydroponic to traditional as well as the hydroponic grown under the different LED lights.
- Students will be assessed based off the completion of the data log worksheet

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Other Evidence:

- As a class, students will create a list of things they think are necessary to live on Mars.
- At the end of the lesson - they will revise their list, based on their findings.
- Students will write short answers to questions provided by the teacher.

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Stage 3 – Learning Plan

Learning Activities:

- Watch two NASA videos about growing plants in space
  Space Station Live: Cultivating Plant Growth in Space (5:08)
  https://www.youtube.com/watch?v=9MfWARdoF-o
  Space Station Live: Lettuce Look at Veggie (4:06)
  https://www.youtube.com/watch?v=c1Gxn_nfgWA
- Discuss the challenges humans have living in space or on another planet for an extended amount of time.
- Work together as a class to make a list of essential items needed on Mars.
- Since food is essential, and weight is restricted, we'll have to grow plants during travel and on the planet, using what is already there.
- Discuss the challenges faced with growing plants in space.

Plant Need	**Why It's Important**	**Challenges in Space**
Water	Water is required for photosynthesis and transpiration; it also aids in the absorption of some nutrients.	Water is heavy to transport, so astronauts pack only the what they need for survival. In low gravity, traditional watering is not an option because water droplets bounce off the soil surface. Water must be directly applied to and

		absorbed by growing media, or incorporated into the media.
Air	Plants take in carbon dioxide (CO2) and oxygen (O2) to use during photosynthesis. People provide carbon dioxide through respiration.	Air doesn't circulate naturally in space. The oxygen released by plants during photosynthesis can accumulate around them and lead to plant death unless fans keep the air moving. Other gases harmful to plants can also collect inside spacecraft and must be removed.
Light	Plants capture light energy for use in photosynthesis, the process by which plants make food.	Spacecraft have few windows, so growing plants requires artificial light. Lights must be energy efficient to avoid overtaxing limited energy resources.
Nutrients	Plants require certain minerals for proper biological function and growth. Nutrients occur naturally in soil on Earth as a byproduct of the decomposition of organic matter or they can be added through applications of fertilizer.	Lunar and martian ground lacks the nutrients plants need, so nutrients must be brought to these sites. Scientists are investigating ways to recycle waste to provide nutrients for plants.
Growing Media	Plants need somewhere to grow. On Earth, most crops grow in soil.	The weight of traditional garden soil and potting mixes makes them impractical in space. Scientists are experimenting with different media such as gels and soilless mixes, along with techniques like hydroponics to devise an acceptable alternative to soil. Additionally, the low-gravity environment changes the way roots, shoots, and water behave in space, so the design of growing containers must help plants overcome

		the effects of reduced gravity

- Discuss the light challenges and what kind of light is needed to grow plants.
  Plants harness energy from the Sun through the process of photosynthesis, which converts light energy into chemical energy. Plants then store this chemical energy within their molecular bonds as sugar. To fuel photosynthesis, plants need light, water, and carbon dioxide. Sunlight isn't the only light that can fuel photosynthesis. Scientists have been experimenting with how to grow plants under "artificial" conditions in space using light-emitting diodes (LEDs) instead.

  The chlorophyll within plants absorbs red and blue light. (Chlorophyll can't absorb green light; that's why green light passes through to our eyes when we look at plants.) Scientists have discovered that some plants need only red light for photosynthesis, so NASA is experimenting with using red LEDs to grow plants in a lab.

Hydroponic Lab Project
- The best simulation of growing plants in space, is to grow them hydroponically.
- For this experiment, students will not only learn how hydroponic plants grow but they will also understand how plants use light for energy.

Time Needed: 50 minutes to set up - Several weeks to gather data
Materials Needed (per class):
- A set of 24 matching plants (We recommend romaine.)
- Five Hydroponic Growing Trays (to plant four plants in each) in which there is room for an insert.
- One regular plant tray (to plant four plants)
- Lightweight, sterile growing material, like perlite, aggregate or rockwool
- Hydroponic nutrient solution
- 20 Cotton or Nylon Wicks
- Potting Soil
- Measuring cup
- 4 Colored LED Lights (red, green, blue, yellow)
- 4 Enclosed structures or coverings that block natural sunlight
- Watering Log
- Growth Measuring Tool
- Camera

Procedure:
- Students set up six trays of plants with four plants per tray.
- One regular tray will be planted with four romaine seedlings in regular potting soil.
- Five trays are hydroponic growing trays with inserts, holding four plants each.
  - Fill the top containers with the lightweight, sterile growing material.

- Fill the bottom containers with the nutrient solution according to the instructions on the package.
- Carefully remove the existing soil from your lettuce and then plant in the top container.
- As you plant, you will also insert the cotton or nylon wick among the roots and string it through a hole in the bottom of the top container. This wick will be used to move the nutrient solution up to the plant roots.

- Once all 24 plants have been planted, students must weigh them and record the weight of each tray.
- Place four hydroponic trays each in their own enclosures, completely blocking sunlight. Inside each enclosure is a different color LED light. Green, blue, red and yellow.
- The fifth hydroponic tray and the regular potting soil tray should be placed near a window for natural sunlight.
- As your plants grow in the hydroponic trays, keep the nutrient solution level constant by adding water as it evaporates and is transpired, and change the solution every week or two. Try to keep the nutrient solution pH between 5.8 and 6.5 and the temperature at about 70 degrees F. Keep track of how much water is used.
- Also keep track of how much water is used with the regular potting soil tray.
- Keep your LED lights on for 12 hours a day.

Assessment:

- Check on plants daily. Take pictures. Students can use the worksheet below to keep track of their data.
- At the end of several weeks, students can chart their findings.
- Go back to your original list of essential items needed to colonize Mars. How would the students adjust that list?
- Use the following questions for students to write short-answers.
    - Compare your plants grown hydroponically and traditionally with potting soil. Did you observe any differences? What were they? What do you think caused them?
    - Compare the plants grown in LED lights to those grown in sunlight. Which grew better? Why?
    - Which color light seemed to help the plants thrive? Why?
    - Why was it important to have more than one plant in each colored-light group?
    - How would you change the experiment if you did it again? Why?
    - Was there a result that surprised you? If so, explain why.
    - Can you think of any purposes of soil that are not fulfilled by hydroponics?
    - Which method used water most efficiently? Which method do you think would be better for plants grown in space?
    - Based on what you learned through this experiment, do you think it’s possible to grow plants on Mars? Why?

Data Charting Worksheet

Student Name: ___________________________________ **Date:** ____________________

Week #: ________ **Tray #:** ________

Plant 1

Data	Day 1	Day 2	Day 3	Day 4	Day 5
Height					
Leaf Structure (firm, wilted, etc…)					
Leaf Color					
Number of Leaves					
Overall Plant Health					
Soil Ph					
Amount of Water Used					

Plant 2

Data	Day 1	Day 2	Day 3	Day 4	Day 5
Height					
Leaf Structure (firm, wilted, etc…)					
Leaf Color					
Number of Leaves					
Overall Plant Health					
Soil Ph					
Amount of Water Used					

Plant 3

Data	Day 1	Day 2	Day 3	Day 4	Day 5
Height					
Leaf Structure (firm, wilted, etc…)					
Leaf Color					
Number of Leaves					
Overall Plant Health					
Soil Ph					
Amount of Water Used					

Plant 4

Data	Day 1	Day 2	Day 3	Day 4	Day 5
Height					
Leaf Structure (firm, wilted, etc…)					
Leaf Color					
Number of Leaves					
Overall Plant Health					
Soil Ph					
Amount of Water Used					