Plant Growth Habitat
Engineering Design Challenge

NASA astronauts Jessica Watkins and Bob Hines work on the XROOTS investigation.
Image Credit: NASA

Lesson Overview:

Plants are essential for humans to survive. As humans explore space, plants can be used for both aesthetic and practical reasons. Astronauts enjoy fresh flowers and gardens on the International Space Station because they create a beautiful atmosphere and let the astronauts take a little piece of Earth with them on their journeys. Plants are good for our psychological well-being on Earth and in space. They also will be critical for keeping astronauts healthy on long-duration missions.

The Plant Growth Habitat challenges learners to select a flowering plant and design a prototype plant growth habitat that could be used on the Moon or anywhere beyond Earth. The plant growth habitat must provide all the basic abiotic requirements to sustain plant life. Learners will also be challenged to design and build a pollinator.

Partner

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National Institute of Aerospace

Plant Growth Habitat

Engineering Design Challenge

This instructional plan follows the 5E instructional model.

Engage | Explore | Explain | Extend | Evaluate

Instructional Objectives

Design #1

- Select a flowering plant species suitable for plant growth beyond Earth and describe what abiotic components are needed for plant growth.
- List all the subsystems needed to support the selected plant species.
- Design a technological device that will meet the needs of the selected plant and present that design for peer review.

Design #2

- Design and create a 2D model (graphic/illustration) and or 3D model of a system to pollinate flowering plants.

National Standards

Next Generation Science Standards (NGSS)

- LS1.B: Growth and Development of Organisms
- LS2.A: Interdependent Relationships in Ecosystems
- Crosscutting Concepts - Systems and System Models
- Science and Engineering Practices - Developing and Using Models, Constructing Explanations and Designing Solutions
- 3-5-ETS1 Engineering Design
- MS-ETS1 Engineering Design

International Technology and Engineering Educators Association (ITEEA) Standards for Technological and Engineering Literacy (STEL)

- STEL 7 Design in Technology and Engineering Education
- STEL 8 Applying, Maintaining, and Assessing Technological Products and Systems

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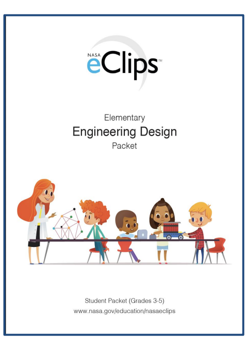


NASA eClips has developed an open-ended design packet to introduce learners to a formal design process.This open-ended packet can be applied to any design challenge and can be used to enhance existing curriculum. Use this link to access the NASA eClips Engineering Design Packets.

https://nasaeclips.arc.nasa.gov/resources/guides#Engineering_Design_Packet

Engage | Explore | Explain | Extend | Evaluate

Materials List

Design #1 - Plant Growth Habitat

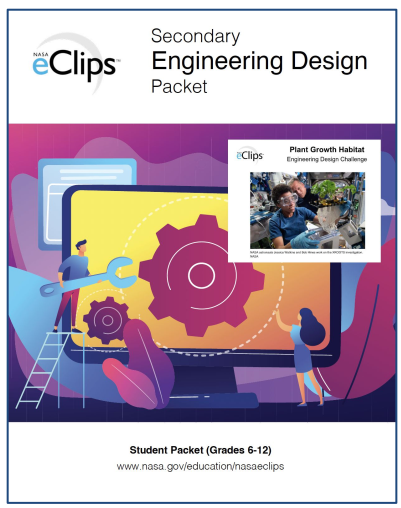
- pencils and color markers
- cardboard, foam core board, corrugated plastics, wood
- hot glue and tape
- scissors
- substrates, plants
- ripstop nylon (like for kites), aerated fabric, or Aquascape Fabric
- fasteners
- electrical components for lighting (LED lights, wires, batteries, electrical tape)
- plastic tubings
- self-watering wicks
- Sensors (optional)
- 3D drawing/modeling programs (optional)

Design #2 - Pollinator

- computer with Internet access and 3D drawing/modeling programs
- pencils and color markers
- hot glue and tape
- structural components like wood and acrylic
- fasteners
- electrical components (small motors,wires, batteries, electrical tape)
- scissors

A customized learner Engineering Design Packet for the Plant Growth Chamber can be found at this link

Click here to make a copy



Safety First

Always stress safety protocols for all science experimentation and engineering design.
If you don't already have protocols in place, follow NSTA's Safety Statement.
httP-s://www.nsta.org/toP-ics/safety:

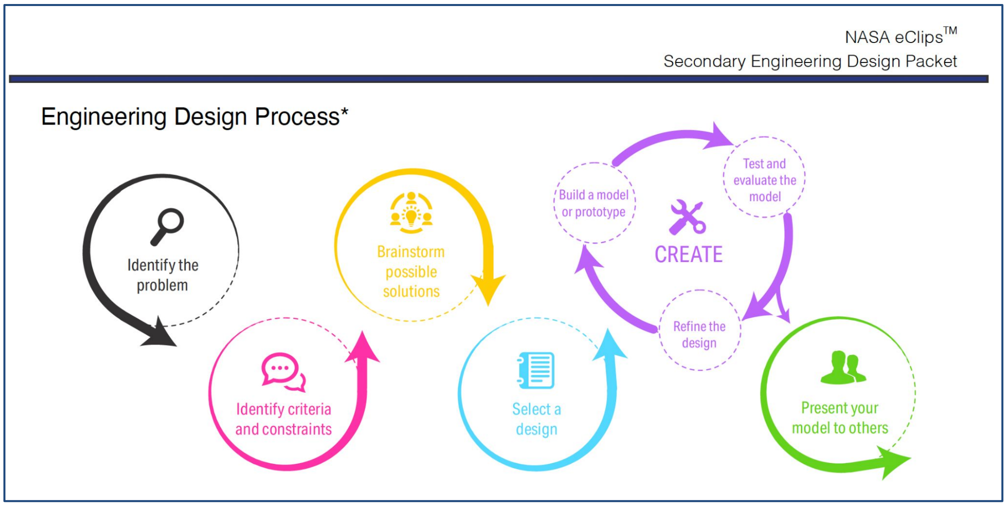
NSTA Safety Acknowledgment Forms (PDF)
Elementary: School
Middle School
High School

Engage | Explore | Explain | Extend | Evaluate

Engineering Design Lesson Development

Engineering Design Process and Plant Growth Habitat Introduction (10 minutes)

1. Explain to your learners that they are being challenged to design, build, and test a ***Plant Growth Habitat.*** To do this, they will work through the engineering design process (EDP) as a team. Share the EDP image and probe to discover learners' prior knowledge of EDP.



Steps of the engineering design process:

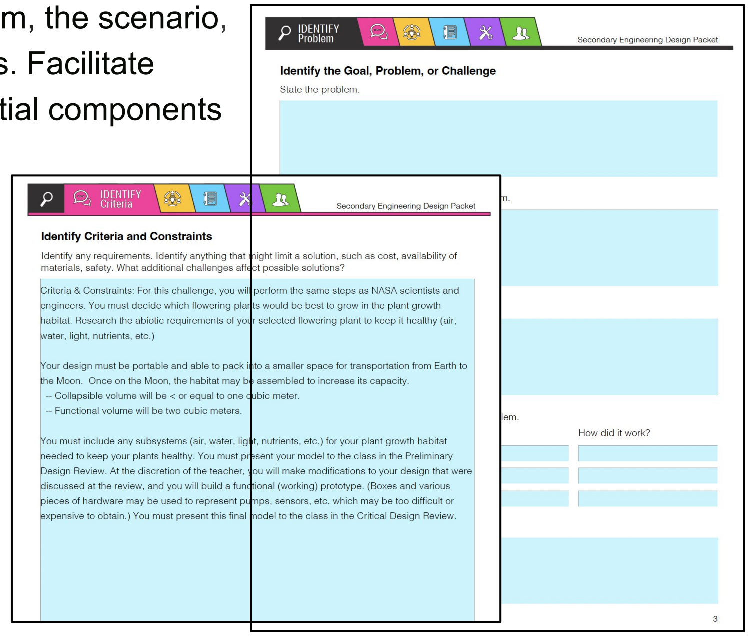
- Identify the problem.
- Identify criteria and constraints.
- Brainstorm possible solutions.
- Select a design.
- Build a model or prototype.
- Test and evaluate the model.
- Refine the design.
- Share the design.

2. Share the scenario and problem statement with learners. These are included in the customized Elementary and Secondary Engineering Design Packets.

Scenario:
Plants are critical for keeping astronauts healthy on long-duration missions. On the space station, resupply missions provide freeze-dried and prepackaged meals to meet astronauts' dietary needs. When crews travel further into space, for months or years, the vitamins in prepackaged form break down. Nutrients can be provided through growing fresh fruits and vegetables. The challenge is how to do that in a closed environment without sunlight or Earth's gravity. (Growing Plants in Space, NASA).

Problem:
You and your team are studying plant growth on the Moon. Your team must:
1) select a flowering plant for experimentation;
2) research the abiotic needs of the plant
and subsystems that support the growth of this plant on Earth; and 3) design a prototype lunar plant growth habitat that will provide all the basic requirements to sustain plant life on the Moon.

3. Ask learners to review and discuss, as a team, the scenario, problem statement, and criteria and constraints. Facilitate discussions and questioning around the essential components of the challenge as a large group.


IDENTIFY Problem
Secondary Engineering Design Packet
Identify the Goal, Problem, or Challenge
State the problem.
How did it work?
3

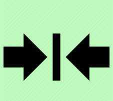
IDENTIFY Criteria
Secondary Engineering Design Packet
Identify Criteria and Constraints
Identify any requirements. Identify anything that might limit a solution, such as cost, availability of materials, safety. What additional challenges affect possible solutions?

Criteria & Constraints: For this challenge, you will perform the same steps as NASA scientists and engineers. You must decide which flowering plants would be best to grow in the plant growth habitat. Research the abiotic requirements of your selected flowering plant to keep it healthy (air, water, light, nutrients, etc.)

Your design must be portable and able to pack into a smaller space for transportation from Earth to the Moon. Once on the Moon, the habitat may be assembled to increase its capacity.
-- Collapsible volume will be < or equal to one cubic meter.
-- Functional volume will be two cubic meters.

You must include any subsystems (air, water, light, nutrients, etc.) for your plant growth habitat needed to keep your plants healthy. You must present your model to the class in the Preliminary Design Review. At the discretion of the teacher, you will make modifications to your design that were discussed at the review, and you will build a functional (working) prototype. (Boxes and various pieces of hardware may be used to represent pumps, sensors, etc. which may be too difficult or expensive to obtain.) You must present this final model to the class in the Critical Design Review.

Criteria are conditions that must be met to solve the problem.



Constraints are things limiting a solution, like cost, safety, materials...

Criteria & Constraints:

For this challenge, you will perform the same steps as NASA scientists and engineers. You must decide which flowering plants would be best to grow in the plant growth habitat. Research the abiotic requirements of your selected flowering plant to keep it healthy (air, water, light, nutrients, etc.)

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-- Collapsible volume will be less than or equal to one cubic meter.

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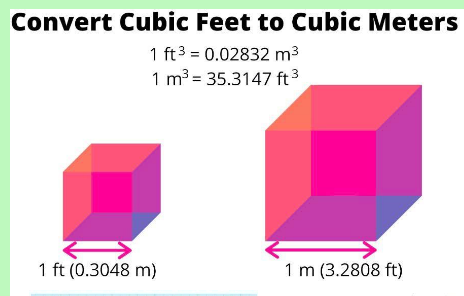
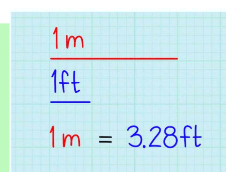




You must include any subsystems (air, water, light, nutrients, etc.) for your plant growth habitat needed to keep your plants healthy. You must present your model to the class in the Preliminary Design Review. At the discretion of the teacher, you will make modifications to your design that were discussed at the review, and you will build a functional (working) prototype. (Boxes and various pieces of hardware may be used to represent pumps, sensors, etc. which may be too difficult or expensive to obtain.) You must present this final model to the class in the Critical Design Review.

Some questions learners might ask include:

a. What materials are available?
b. Can plants be grown in Moon dirt (regolith) ?
c. How much water do plants need to grow?
4. Do plants need an atmosphere to grow?

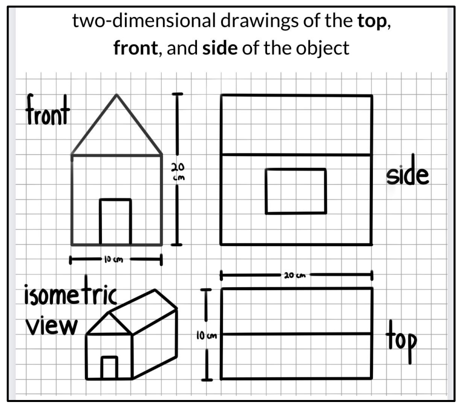
Engage | **Explore** | Explain | Extend | Evaluate

Plant Growth Habitat Research, Brainstorm, Plan and Create (40 - 60 minutes)

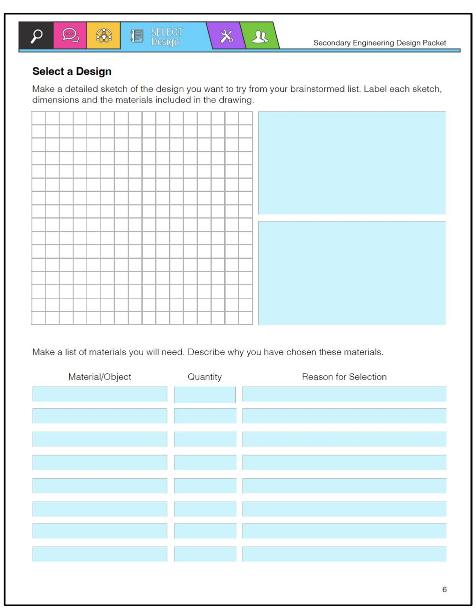
1. Brainstorm ideas and help learners find research resources and links to answer questions such as:
   a. What do flowering plants need to grow? Research and list all requirements your plants need to stay healthy. Include nutrients, temperature, lighting, etc.
   b. What are the challenges of growing plants in space or on the Moon?
   c. Identify methods used to grow plants on the International Space Station.

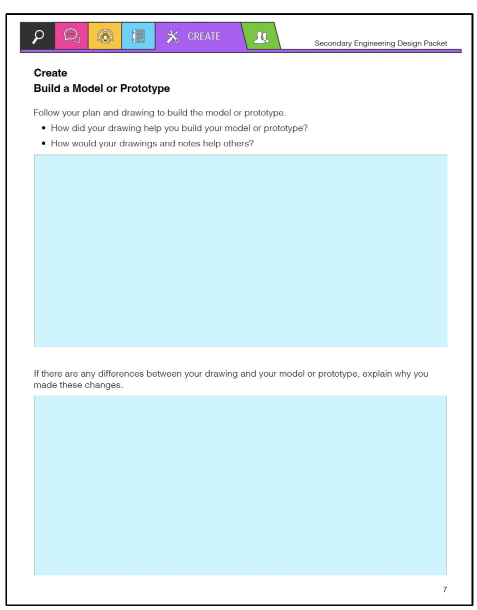
Several resources are already added to the customized Engineering Design Packets. You may add others, if you choose.

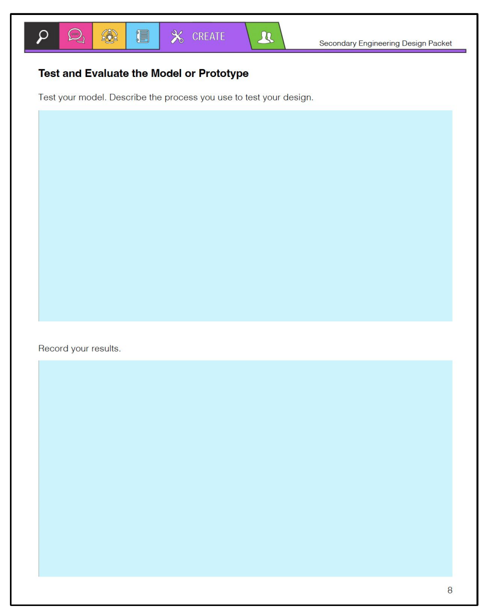
2. Once learners have more knowledge about plant growth, ask them to brainstorm possible solutions to the challenge. Encourage learners to make detailed drawings of their solutions in their EDP packet.



3. Continue to use the EDP packet to guide learners through the next steps of the design process.
   - o Select a design
   - o Build a model or prototype
   - o Test and evaluate the model or prototype
   - o Refine the design







Plant Growth Habitat Review and Explain (20-30 minutes)

1. Run a Preliminary Design Review where teams share their innovations with one another, verifying that their designs work.

2. Ask students to use and apply related vocabulary as they describe their designs.

3. Show one of the NASA eClips TM video segments to learners.

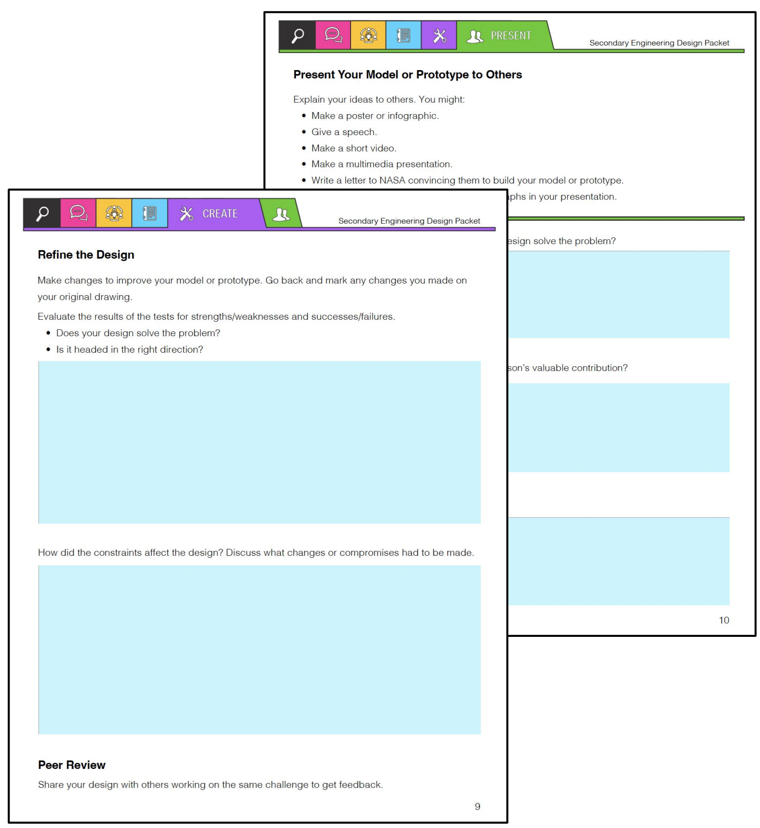
Our World "Systems to Grow Plants in Space"
https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-systems-to-grow-plants-in-space

Our World "Plants in Space"
https://nasaeclips.arc.nasa.gov/video/ourworld/our-world-plants-in-space

Ask SME "Technical & Horticultural Scientist - Jacob Torres"
https://nasaeclips.arc.nasa.gov/videosingular/asksme/technical-horticultural-scientist-jacob-torres

4. In their engineering design packets, ask learners to reflect and sketch diagrams of possible improvements to their plant growth habitat. Share responses.

5. Discussion question: How do these systems compare with the systems NASA uses to grow plants in space.



PRESENT Secondary Engineering Design Packet

Present Your Model or Prototype to Others

Explain your ideas to others. You might:
- Make a poster or infographic.
- Give a speech.
- Make a short video.
- Make a multimedia presentation.
- Write a letter to NASA convincing them to build your model or prototype.

...phs in your presentation.

...esign solve the problem?

...son's valuable contribution?

10

CREATE Secondary Engineering Design Packet

Refine the Design

Make changes to improve your model or prototype. Go back and mark any changes you made on your original drawing.

Evaluate the results of the tests for strengths/weaknesses and successes/failures.
- Does your design solve the problem?
- Is it headed in the right direction?

How did the constraints affect the design? Discuss what changes or compromises had to be made.

Peer Review

Share your design with others working on the same challenge to get feedback.

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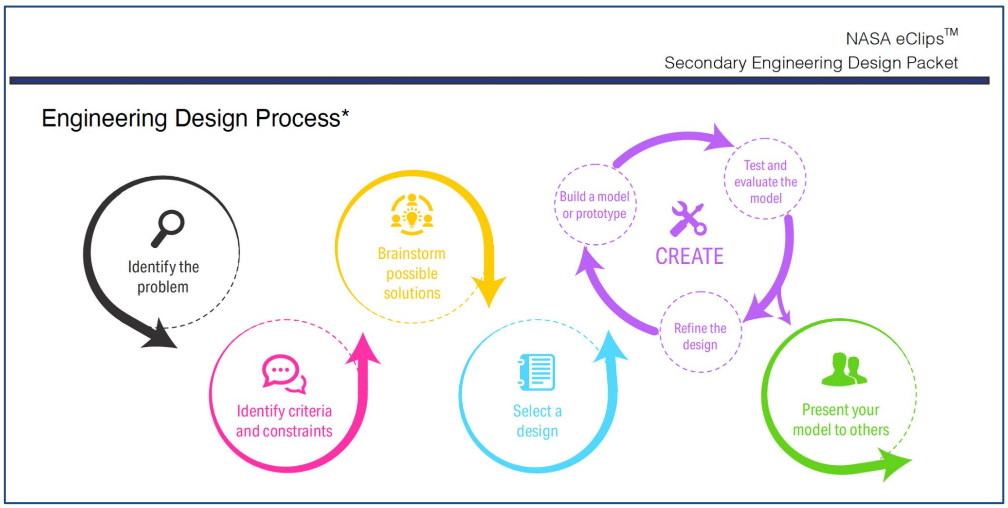
Plant Growth Habitat Extend (50 minutes)

1. Guide learners through the design process for their second design challenge:

Problem Scenario:
Flowering plants need to be pollinated to produce fruits and vegetables. Space does not have the natural pollinator that we have on Earth. Design and create a pollination system for flowering fruit or vegetable producing plants growing in space.

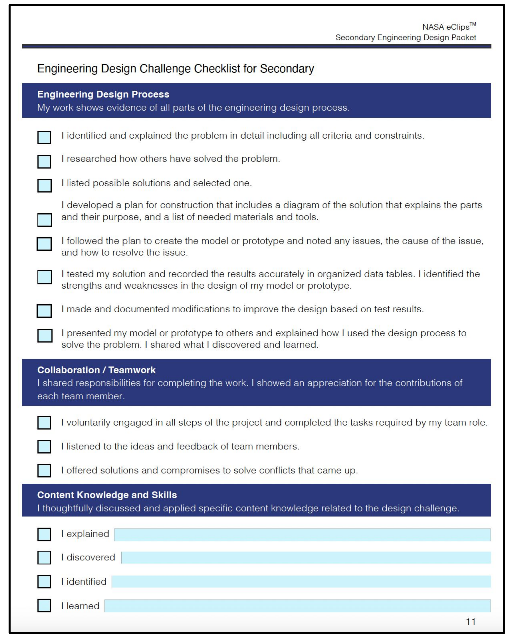
Criteria and Constraints:
Your pollinator:
- must collect pollen from one flower and deliver it to another flower.
- cannot damage the flower.
- must be operated by one person.



2. Use these questions to facilitate critical and creative thinking as groups work through the EDP steps.

   - How is your solution modeling the behavior of pollinators?
   - How might it help the plant?
   - How might it hurt the plant?
   - Estimate the number of plants your design could pollinate in one hour?
   - How easy is it to operate?
   - How will your design help solve the problem of not having pollinators in space?

3. Learners can make an infographic describing the pollinator. The infographic can include:
   - Descriptions and drawings to highlight the benefits, and identify any harmful components
   - Ease of use
   - Time and process for pollination



NASA eClips™
Secondary Engineering Design Packet

Engineering Design Challenge Checklist for Secondary

Engineering Design Process
My work shows evidence of all parts of the engineering design process.

- ☐ I identified and explained the problem in detail including all criteria and constraints.
- ☐ I researched how others have solved the problem.
- ☐ I listed possible solutions and selected one.
- ☐ I developed a plan for construction that includes a diagram of the solution that explains the parts and their purpose, and a list of needed materials and tools.
- ☐ I followed the plan to create the model or prototype and noted any issues, the cause of the issue, and how to resolve the issue.
- ☐ I tested my solution and recorded the results accurately in organized data tables. I identified the strengths and weaknesses in the design of my model or prototype.
- ☐ I made and documented modifications to improve the design based on test results.
- ☐ I presented my model or prototype to others and explained how I used the design process to solve the problem. I shared what I discovered and learned.

Collaboration / Teamwork
I shared responsibilities for completing the work. I showed an appreciation for the contributions of each team member.

- ☐ I voluntarily engaged in all steps of the project and completed the tasks required by my team role.
- ☐ I listened to the ideas and feedback of team members.
- ☐ I offered solutions and compromises to solve conflicts that came up.

Content Knowledge and Skills
I thoughtfully discussed and applied specific content knowledge related to the design challenge.

- ☐ I explained
- ☐ I discovered
- ☐ I identified
- ☐ I learned

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Plant Growth Habitat Evaluate (20 minutes)

1. Guide learners to the Evaluation Checklist in the Design Packet for their self-evaluation to assess their understanding and use of the engineering design process to solve the challenge.

2. Ask teams to compare these plant growth habitat attributes:
   - What is the size of your lunar plant growth habitat?
     - Length: ____________
     - Width: ____________
     - Height: ____________
   - Does your lunar plant growth chamber meet the size criteria and constraints?
   - Does your electrical circuit work? How do you know?
   - Does your watering system work? How do you know?

3. Provide time for groups to share their designs during a Critical Design Review.

Resources

Plant Pillows in Space (July 12, 2019)
https://www.sncorp.com/news-archive/plant-pillows-in-space/

Veggie Fact Sheet
https://www.nasa.gov/sites/default/files/atoms/files/veggie_fact_sheet_508.pdf

Growing Plants in Space
https://www.nasa.gov/content/growing-plants-in-space

NASA's Plant Science is Rooted in Earth and Shoots for the Stars
https://science.nasa.gov/science-news/biological-physical/nasa-plant-science-is-rooted-in-earth-and-shoots-for-the-stars

NASA Teams Persevere Through Plant Challenges in Space
https://www.nasa.gov/feature/nasa-teams-persevere-through-plant-challenges-in-space

Growing Plants in Space
https://www.ars.usda.gov/oc/utm/growing-plants-in-space/

Ways the International Space Station Helps Us Study Plant Growth in Space
https://www.nasa.gov/mission_pages/station/research/news/Ways-the-ISS-Helps-Study-Plant-Growth

A Novel Approach to Growing Gardens in Space
https://science.nasa.gov/science-research/science-enabling-technology/technology-highlights/a-novel-approach-to-growing-gardens-in-space/