Note! This was originally Lesson 4 (out of 8 lessons) in the NESSP Artemis III ROADS Student Challenge and Companion Course.

Learn more about NESSP here.

Growing Food on the Moon

Lesson Level Question: *How can we make a plan for feeding astronauts on the Moon?*

Goals and Objectives:

- Understand the amount of time and/or resources (inputs) that it takes to produce calories from plants (output).
- Plan and conduct an investigation in order to produce evidence about time and/or resources (inputs) that are needed to produce food (output) from plants.
- Use evidence from their investigation and other sources to create an agricultural plan for astronauts on the Moon.

Lesson Summary*: First, students will consider what plants they have eaten recently, as well as why we eat. Then, they will plan and carry out investigations to help them learn about the inputs (time, water, soil, fertilizer, labor, etc) that are required to produce food (output) from plants. They will use what they learn from their experiments and other sources to make an agricultural plan with a claim of what will be required to produce food on the Moon.*

Tips for Expediting This Lesson: *In Explore, consider choosing a fast-growing plant such as microgreens, bean sprouts, fast-growing lettuce, or radishes. You may also wish to start the plant experiment for Explore and then move on to other lessons while you monitor plant growth over a period of time, then come back and continue with the lesson after plants have produced.*

Standards Links: *Click here for information about standards alignment for NGSS, CCSS ELA and Math, and more.*

Materials Provided by the Teacher	5 E Lesson Summary

Basic materials for plant investigation designed by students. These could include: Grow light Digital Scale Seeds and/or dried beans Soil Plastic cups or baggies Fertilizer	**ENGAGE**: Students will consider all of the plants that they have eaten over the past week, including locally or culturally important plant foods. Then, they will consider the reasons why we eat. **EXPLORE**: Students will plan and carry out an investigation in order to produce evidence about time and/or resources that are needed to produce food from plants. **EXPLAIN**: Students will analyze the data from their investigations in order to make a claim about the number of calories that their plant produced and the amount of time and/or resources that it took to produce the calories. **ELABORATE**: Students will use the data from their investigations as evidence to support a claim about the time and/or resources (inputs) it will take for astronauts to produce food (output) on the Moon. **EVALUATE**: Students will document their work by summarizing their investigation and their agricultural plan. **EXTEND**: Students will investigate the food that is produced and consumed in their local area (OPTION 1) and/or investigate NASA careers related to the work of this lesson (OPTION 2).

Before The Lesson

- Review the deliverables listed in the Evaluate part of this lesson. This will help you understand the goals of this lesson.
- Review the Agricultural Plan Claim Examples so that you know how to guide your students through the Explore, Explain, and Elaborate sections. This handout helps explain "where you're going" so that you can help students get there. This is NOT a student-facing handout.
- **Explore**:
  - Review Teacher Tips for Scaffolding Investigations . Consider how much support you think your students will need. Act accordingly. For example, this may include you filling out parts of the "Planning and Carrying Out Investigations" template for students in advance.
  - Consider the materials that you will make available to students for their plant investigations and how you will manage this section. For instance, will all groups do the same investigation, which is designed by the whole group? Or will individual groups design their own investigations? Will students be allowed to request or bring in materials that you don't initially provide?
- **Elaborate:** Explore the NASA resources (which include text, videos, a podcast, and more) and consider which of the resources might be best for your students to use as part of their agricultural claims.

Lesson Plan

Phase	Middle School	Materials/Prep
Engage (30 Min)	***Students will consider all of the plants that they have eaten over the past week, including locally or culturally important plant foods. Then, they will consider the reasons why we eat.*** Ask students to take a moment to think of everything that they have eaten or had to drink in the past week. Ask them to write down a list of the plants that were consumed (for example, popcorn is a food that comes from a plant, the plant is corn). Give them two minutes to brainstorm a list on their own, then pair students together to share their lists and keep adding plants or plant-based foods. Give pairs 5-10 minutes to work together. If students are having trouble coming up with a list of plants that they ate, consider showing Slides 1-5 (linked in the	Engage Slides En Español Engage Slides E…

sidebar, with the teacher notes hidden). It is almost a guarantee that each student has eaten many of the plants shown in this slide show in the past week…but do they know what the plants are? Give them a few minutes to work with their partner on this task.

Consider important food plants that are grown locally, consumed locally, or both. Make a copy of the slide deck and add photos of these plants.

If you live in the Pacific Northwest, this has been done for you on Slides 6 and above (link in sidebar). You can use the last slide to make your own examples, or you can have the students use it to make their own examples.

Then, go around the room asking each student or pair to share a plant that they ate in the past week. Once one student has called out a plant, others should check it off the list. Maintain a class list on the board and go around until all plants have been mentioned. If students did not name any of the plants pictured in the slides, reveal these plants and what parts of them we eat.

NOTE: Some students might state that animal products (like meat, milk, or honey) come from plants originally, and this is true. Whether we eat them directly (primary consumption), or eat things that rely on plants (secondary consumption), it all goes back to plants!

If you have time, consider doing one or both parts of “OPTION 1” in the EXTEND section below. These activities allow students to investigate both the food that is produced in their local area and sent to people elsewhere AND food that is available in their local area from around the world. Scroll down to “EXTEND” to check out these activities.

Next, ask students WHY we eat food. Ask them to consider as many reasons as they can, and if some reasons are more important than others. After a moment of private think time, they can discuss the question in pairs before sharing as a whole group.

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<td>Students’ responses to the question “why do we eat?” will vary based on their grade level and prior knowledge. Accept all ideas and answers and consider how student answers reveal their thinking about food and the body.

Elementary students or students with limited prior knowledge in this area may say things like:
● Because food tastes good
● Because we feel hungry
● Because we need food to grow

Secondary students or those with prior knowledge in this area may say things like:
● We need (or our cells need) food for energy (calories)
● We need vitamins and minerals to be healthy

Students with advanced knowledge or those who think outside the box may mention words like metabolism or comment on the cultural and social importance of foods (such as eating at family gatherings or holidays).</td>
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If students don’t mention these ideas, use probing questions such as:
● If no one mentions energy: Ask what would happen if we didn’t eat. Students may say that we would lose weight or eventually die / starve. One reason we eat is to stay alive!
● If students mention energy but not calories: Ask if they have heard the word “calories” and what they understand about the word. Calories are a measure of how much energy is in food. We take in calories when we eat and then those calories provide the energy we need to live, move, and think.
● If no one mentions eating because food tastes good: Ask how they decide which foods to eat and not to eat, or if they would be willing to eat nothing but their least favorite food!

Shift to talking about the needs of future astronauts on the Moon. NASA sends a lot of food to space that is dried or frozen to last a long time! Longer term missions will require astronauts to grow some of their own food so that they have fresh, tasty food that is easy to transport as seeds and can be grown on site. NASA does a lot of experiments on plants so that they can be sure that astronauts have tasty, easily grown food that provides the calories they need to live and work on the Moon.</td>
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<td>Explore

(120 Min plus observations of plant experiments daily over</td>
<td>Students will plan and carry out an investigation in order to produce evidence about time and/or resources that are needed to produce food from plants.

Choose a common plant that many students eat. Ask them to guess how long it takes to produce food from that plant. Then, search “_________ how long from plant to harvest” where that plant they chose goes in the blank. Here are a few plants (from the Engage slides) you can use to compare.
● Corn: depends on the type of corn (flour, sweet, pop). It usually takes between 60-120 days.
● Wheat: Spring wheat takes 100-130 days to grow. Winter wheat takes 180-250 days to grow.
● Beets: Take 50-70 days</td>
<td>Teacher Tips for Scaffolding Investigations

Planning and Carrying Out Investigations Template (English)</td>
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- Olives: Trees start producing fruit after 3 years. Then harvest yearly in the autumn.
- Sunflowers: Take 70-100 days
- Cocoa: Takes 5-6 years to give its first fruits.

NOTE! Try to choose plants <u>from your students' list</u> that are very different in growing time, such as lettuce (which takes as little as 30 days) and cherries (cherry trees take 4 to 7 YEARS to start producing cherries). In general, tender crops like lettuce, other greens, and radishes are quick, whereas crops that grow on trees (peaches, nuts, apples) take a long time. Plants that NASA has grown in Space include: Lettuce, Radishes, Tomatoes, Cabbage, Mustard Greens, Peppers. Up next, NASA plans to grow Berries and Beans.

SAY: One way to think about growing plants is to consider **inputs** that are required to produce food (**output**). For many foods we eat, inputs include seeds, water, soil, time, light, and labor or work to tend to the plants. Other inputs might include fertilizer and other chemicals to fight pests and plant diseases. The output is the food that we harvest and eat.

Say: We are going to plan and carry out an investigation to help us understand the inputs that it will take to grow food for astronauts on the Moon.

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The goal of all of these investigations is the same--students should plan an investigation to produce evidence about time and/or resources (inputs) that are needed to produce food from plants (output). However, this part of the lesson will look very different depending if you will take a directive, collaborative, or supportive stance as students plan the investigation. Your stance should be based on your students' prior experiences with planning and carrying out their own investigations. Review the "*SCAFFOLDING TIPS*" document linked in the sidebar. Some ways to structure this portion include:

- <u>**Directive Stance (MOST SUPPORT):**</u> You choose a testable question and the materials, all groups investigate the same testable question. You give the students a lot more specific directions, explaining why those directions are important or make sense.
- <u>**Collaborative Stance**</u>: Between "Directive" and "Supportive" stances. You may provide more support in some areas (like what materials are available and examples of testable questions) and less support in other areas. Circulate as students plan and ask probing questions if students are off track or need more support.
- <u>**Supportive Stance (LEAST SUPPORT):**</u> You give students little support ahead of time, but circulate as they plan and ask probing questions from the Scaffolding Tips table. If you notice groups of students struggling with a particular idea or step, you may hold a short meeting where you bring them together for support on that specific topic.

In all cases, the goal is for you to provide the **minimum amount of support** that will allow your students to succeed and to **allow students to make as many decisions and choices as possible.**

Elementary: Focus on measuring time and plant mass, which can be used to find calories, so

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<u>En Expañol</u>

Basic materials for plant investigation designed by students. These could include:
Seeds and/or dried beans
Soil
Plastic cups or baggies
Fertilizer

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	that students can make a claim about the rate of calorie production. **Secondary (middle and high school):** Measure at least one other type of input, which could include water, fertilizer, light, labor (active time caring for the plants), etc.

Ask students what they would need to do, including what decisions they might need to make and what they would need to observe or measure in order to make a claim about how long it takes to grow calories for astronauts on the Moon. Students might say things like:

- Decide what type of plant to grow. (If they don't say this, remind them of previous parts of the lesson and ask if all plants take the same amount of time to grow.)
- Need to know the materials we have, including the type of seeds. (If they don't say this, it might be helpful to show them the "Planning and Carrying Out Investigations Template."
- Need to know how to measure or find out calories. (If they don't mention this, ask them if a tiny leaf of lettuce has the same calories as a huge head of lettuce. How will we know how "much" lettuce we have? Students should come around to measuring the size (or mass) of the food you produce.

	Consider providing seeds of locally/culturally relevant plants that students mentioned in the Engage section, for use in their science investigation. Looking for inspiration based on your local culture or traditions? [Check out this list of suggested seeds]() to use in the experiment or do some research to discover locally relevant seeds in your area. Some local resources you could seek out for suggestions include: ● Tribal centers or other tribal resources ● County Cooperative Extensions or Soil Conservation District ● Master Gardeners' organizations

Give students access to the "Planning and Carrying Out Investigations" template. Direct them to fill out parts 1-5 of the template as they plan their investigations. In addition to what is in the Planning and Carrying Out Investigations template, you may also wish to ask students to create a calendar for the duration of the investigation, clearly noting when they will make observations or take measurements. This is important in longer-term investigations like those involving plant growth.

Be sure students are taking the measurements and observations that they will need to make claims. This could include weighing the dry seeds ahead of time (especially if they are going to make "sprouts" as food), the amount of water or other resources added, tracking the time they spend tending to the plants, etc. It is also important that students are aware at this point of what will be required in the Evaluate section of the lesson. For their experiment, this will include:

- A drawing or picture of the experiment with the independent, dependent, and controlled variables labeled.
- Information on the frequency of measurements and when measurements were taken.
- At least three photographs of their experiment in progress that are dated with a description or caption.
- The experimental data in table or graphical form.

These notes are provided as guidance for TEACHERS, and should not be shared with students. You should work

	with students using tips and questions from the SCAFFOLDING TIPS document. Many other kinds of investigations are possible, and these are provided only to give you some ideas to help you get started in supporting your students to make decisions and plan their investigation. ● **EXAMPLE 1: How does the type of lettuce we choose to grow affect how quickly we can produce food for astronauts?** Choose 2 or 3 different kinds of fast-growing lettuce (e.g. lettuce types grown by NASA include Red romaine lettuce, Green lettuce, and Mizuna mustard greens). Refer to this NASA document to learn more! ○ Red romaine lettuce: you can start harvesting outer leaves 21 days after sowing ○ Mizuna mustard green: can be harvested after about 30 days ○ Green leaf lettuce: can be harvested between 30–70 days after planting Plant three pots of each kind of lettuce and label them. For example, “Type 1: A - Romaine, B - Romaine, C - Romaine” and “Type 2: A - Mizuna, B - Mizuna, C - Mizuna.” All the pots will receive the same treatment. That is, same potting soil, same amount of natural or LED light, same water (source, amount, pH). Record the date you start your experiment. Record daily observations as the lettuce grows. For example, take a photo of the pots everyday and make note of changes. When it has sprouted/emerged (4-14 days) you will use a ruler to measure the height. You can count the number of leaves. When the plant is ready to harvest, cut off the leaves and weigh them using a food scale (the average head of lettuce is around 300 grams). Use a nutrition facts website to determine how many calories are in the lettuce you produced (e.g. 300 grams = 45 calories). Divide the number of calories by the number of days it took to grow and this will give an idea of the number of calories produced by the lettuce per day. For example, 45 calories divided by 21 days = 2.14 calories per day. ● **EXAMPLE 2: How does the amount of light (# of hours or intensity) affect how many calories a plant can produce?** Use one type of plant or seed. Use grow lights to give one set of plans a different number of hours OR a different intensity of light over a period of time. After the plants have produced food, harvest and measure the mass of the plans, divide by the number of days, and compare the two groups. ● **EXAMPLE 3: Science symposium approach.** Different groups in the classroom test different testable questions. For example, one group may alter the amount or intensity of light (as described above), other groups might vary water, fertilizer, type of soil, type of plant, etc (with only one variable changing per group). Then, the groups share and combine their results to make claims about ideal conditions to produce the most calories in a given time period. After your plant has produced edible material, use a scale to weigh the material and then use a calorie website to find out how many calories that mass of food contains. (You can use a search engine or various calorie websites. Be as specific as possible about your plant for the best results. For example, search for iceberg lettuce instead of just “lettuce.”)	
Explain (30 Min)	***Students will analyze the data from their investigations in order to make a claim about the number of calories that their plant produced and the amount of time and/or resources that it took to produce the calories.*** If all students did the same investigations, different groups likely still got slightly different data. Have all groups share their data in a manner that allows everyone to access it. What is similar and different about the results? If students did several trials, they may need to average their data and, depending on their grade level and prior math experiences, do other statistical analyses. While younger students may focus on figuring out the rate of calorie production (Calories per day), older or more	

	experienced students may include other ideas, such as Hours of labor per calorie (or per 100 calories or some other number), liters of water per calorie, etc.	
Elaborate (60 Min)	***Students will use the data from their investigations as evidence to support a claim about the time and/or resources (inputs) it will take for astronauts to produce food (output) on the Moon.*** Make sure that you (the teacher) have reviewed the "Agricultural Plan Claim Examples" document (linked in side bar) so that you understand the kinds of things that are expected for this part of the lesson. Teams can work as a group to complete one "Agricultural Plan." Provide teams with access to the "Agricultural Plan Claim Template" and the requirements of the Agricultural Plan form the "Evaluate" section below. Depending on the past experiences of your students, you may have to guide students to understand what the template is asking them to do. Engage in whole group discussion or circulate among groups as they work to support them as they complete their claim. **Grade Level Adaptation:** Middle School and High School students should include citations for external references used as evidence in the agricultural plan, including at least one NASA publication. Some examples of NASA resources can be found linked in the sidebar. Once teams have a draft of all sections on this template, pair up teams so they can share their ideas with each other, get feedback, and finalize their claims.	Agricultural Plan Claim Examples TEACHER FACING DOCUMENT ONLY! Agricultural Plan Claim Template (English) En Español NASA Resources (Text, audio, video, images) about Plants

Evaluate (30 Min)	***Students will document their work by describing their investigation and their agricultural plan.***
	
	There are two final deliverables for this lesson. They are described below. The deliverables should be produced by each team, but all members of the team should be responsible for explaining the deliverables.
	
	• A description of the team's investigation(s) that includes:
	  ○ A drawing or picture of the investigation with the independent, dependent, and controlled variables labeled.
	  ○ Information on the frequency of measurements and when measurements were taken.
	  ○ At least three photographs of their investigation in progress that are dated with a description or caption.
	  ○ The experimental data in table or graphical form.
	  ○ A final conclusion, claim, or finding from their investigation.
	• A description of the team's agricultural plan that includes:
	  ○ A list of claims that describe the number of calories they need to produce, the time, the number of plants,	

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greenhouse size and the amount of water, soil, fertilizer, or grow lights needed.

- Evidence and reasoning to support each of the listed claims, including:
  - A description of any calculations the teams did to scale up the measurements from their investigation.
  - Teams should describe any and all assumptions made when designing their agricultural plan. For example, teams might need to assume that NASA won't be able to grow plants in pure Earth soil.
- Middle and High School teams should include at least one piece of information with a citation to a NASA resource or publication.
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<td>Extend (Optional)</td>
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Students will investigate the food that is produced and consumed in their local area (OPTION 1) and/or investigate NASA careers related to the work of this lesson (OPTION 2).

OPTION 1: Local Food Exploration

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There are two ways to consider your local food environment. First, consider the types of food items that are **produced** in your area. Are these foods only eaten in your local area, or are they sent elsewhere to feed people in other places? You can ask local people about food they produce and if they send any of that food elsewhere for people to eat. You can also search online using phrases like "fruit exports from (your state, county, or community)" or "agriculture products from (your state, county, or community)."

Next, we will think about where the food came from that is **consumed** in your area. Print out the "Maps for Food Exploration" handout (linked in sidebar) and take these maps to your local grocery store. Mark your location before you start. Check stickers and labels on fresh fruit and vegetables to see which state or country produced them and mark them on your map. For processed foods (like boxed dinners, bags of pasta, etc), check labels to see where they were produced.
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DISCUSSION: Whether your students engage in one or both of these tasks, some discussion questions to consider include:

- Why don't we just eat food produced in our area? (Students may say that not all foods that we like will grow here, or that not all seasons are good for growing, or that there isn't a lot of farmland nearby, depending on where you live.)
- How much of the food you eat do you think is produced in our county? What about our state? Our country?
- What food that you eat comes from the furthest away? How long do you think it takes your food to move from where it is produced to where you are? Why might this matter? (Students might say that food will not be very fresh when it arrives, or that it will take a lot of fuel / energy to move the food long distances, or that it might have better weather or climate far away.)

OPTION 2: Career Connection
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Maps for Food Exploration Handouts

Maps for Food Exploration Handouts En Español
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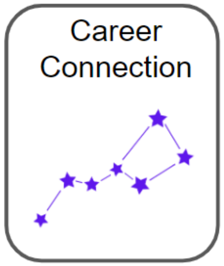

Students will investigate NASA careers related to the work of this lesson.

There are several NASA careers related to this lesson. Explore them all to learn about the people at NASA that could achieve this Mission Objective!

After reviewing the featured jobs, ask students to relate the work that each person does to the parts of this lesson.

You might like this career if you liked….	Job Title	Link to Resource	Type (reading, video, etc)
If you liked growing and understanding plants….	Botanist Grades 3-5	https://rmpbs.pbslearningmedia.org/resource/a-z-career-lab-botanist/botanist/	Video (3:57)
If you liked growing and understanding plants….	Botanist Grades 6-12	SCIENCE: Botanists and Plant Scientists | MyNASAData	Summary page of job description
If you liked thinking about feeding astronauts…	Food Scientist Grades 3-12	Surprisingly STEM: Space Food Scientist - NASA	Video (7:26) and very short text bio
If you liked growing and understanding plants….	Microgravity Plant Scientist Grades 3-12	Surprisingly STEM: Mi…	Video (5:39)

TEACHER TIPS for Scaffolding the "Planning and Carrying Out Investigations Template"

Depending on the amount of previous experience your students have with planning and carrying out their own investigations, you may wish to scaffold their experience through a combination of collaborative planning, additions to the blank "Planning and Carrying Out Investigations Template," and other supports. (NOTE--this template is available at the bottom of this document.) **The goal is to provide the least amount of scaffolding necessary. Tips are listed in order from least support to most support.** The blank Template is below the table. For grade-banded details on this Science and Engineering Practice in the Next Generation Science Standards, visit https://my.nsta.org/ngss/Practices.aspx?id=3

Handout Section	**Scaffolding Tips**
1. Materials.	Note! Depending on your process with students, you may wish to do the Testable Question section with students before the Materials section. ● LEAST SUPPORT: Give students the blank handout and ask them to list the materials and equipment that they want to use for their experiments. This may require some negotiation if they list items that you do not have available. Ask students probing questions about why they need a certain material or tool, if it will be safe to use in the classroom environment, and if we have time to do the experiment they are considering. ● Consider showing students the materials and equipment that are available for the experiment without naming or explaining the items. Ask students to name and list each item on their template, and explain what each item is, what it could be used for, and, for tools, what it measures and how to use it. Students could work in pairs or small groups on this first, and then as a whole class. During the whole-class discussion, clarify any points of confusion. ● MOST SUPPORT: Consider showing students the materials and equipment and listing them in the student template. Ask students to match what they are seeing to the items on the list. Ask students to explain what each item is, what it could be used for, and, for tools, what it measures and how to use it. Students could work in pairs or small groups on this first, and then as a whole class. During the whole-class discussion, clarify any points of confusion. This may include mini-lessons on how to use the tools and equipment that students are unfamiliar with.
2. Testable Question.	Note! Depending on your process with students, you may wish to do the Testable Question section with students before the Materials section. ● LEAST SUPPORT: Give students the blank handout and ask them to formulate a testable question. Pairs or groups of students can investigate different testable questions. ● If students generated a question list earlier in this lesson, refer them back to that question list to see if any of those questions could be tested (or partially tested) in the classroom. ● Consider providing students with some or all of the following scaffolds for testable questions, where IV = Independent Variable and DV = dependent variable. ○ How does ______(IV)______ affect _____(DV)_____?

	○ What is the effect of _____(IV)______ on ______(DV)_____ ? ○ What effect does ______(IV)______ have on ______(DV)_____ ? ● If students do not have previous experience with independent and dependent variables, consider providing examples of testable questions as well as the definitions of IV and DV. This could include: ○ IV = The thing that we change on purpose ○ DV = The thing that we observe or measure to see how the IV affects it. ○ Example: How does the <u>direction of our push (IV)</u> affect the <u>direction the car travels (DV)</u>? ● If students need additional support, consider working with them to brainstorm a list of all of the variables that you can control and/or measure in the classroom. The available materials list can be very useful for this. After you have brainstormed the list, use the testable question scaffolds above to create a testable question that makes sense. ○ For example, if you have thermometers, ask students what variable this allows us to measure (temperature). Then, ask students if we can also control this variable (for example, using ice or a hot plate). ○ If you have rulers, ask students what variable this allows us to measure (length). Then, ask what in our experiment we might measure length for. This might include how far something travels, how much something grows, etc. ● If students need additional support, consider providing testable questions that you are sure you have the materials and equipment to answer. In this situation, you may wish to provide students with testable question options BEFORE discussing materials. Then, students can use the testable question to consider what materials they will need for the investigation. Student pairs or groups may wish to choose different testable questions. ● MOST SUPPORT: Provide a single testable question that all pairs or groups in the class will investigate. In this situation, you may wish to provide students with testable question options BEFORE discussing materials. Allow students to use the testable question to guide their materials list, being sure to include what they will control, measure, or observe.
3. How will your investigation work?	● LEAST SUPPORT: Provide students with the blank handout and ask them to sketch and label their experimental set-up. ● Consider providing cut-out images or an electronic image set of the tools and materials needed, and ask students to arrange and label their experimental set-up. They can do this before the experiment or after the experiment. ● Consider taking a photo or providing a sketch of the experimental set-up and asking students to label it. They can do this before the experiment or after the experiment. ● MOST SUPPORT: Consider taking a photo or providing a sketch of the experimental set-up and asking students to label it using a word bank that you provide. They can do this before the experiment or after the experiment.
4. Experimental Steps	● LEAST SUPPORT: Provide students with the blank handout and ask them to list the steps they will take to do their experiment Circulate and ask guiding questions such as: ○ What will you measure? When will you measure it? How will you measure it? How many times will you measure it (trials)? ○ What will you record or write down? ○ Will that information help us answer the testable question, or will we need more information?

	○ Does your list of steps include each tool or material you plan to use? ○ Does your list of steps include tools or materials that aren't in your material list yet? ● Consider providing a card sort (paper or electronic) where the steps are listed but are not in order. ● MOST SUPPORT: Consider developing the experimental steps together as a class.
5. Expected Outcome	● LEAST SUPPORT: Provide students with the blank handout and ask them to describe what they expect to find out. ● Direct students back to the testable question and predict an answer. Their answer does not have to be specific (quantitative). For example, if the testable question is about relating the strength of a push to the distance a car travels, they can predict using words like "further" and "not as far" rather than providing a numerical prediction of distance. ● MOST SUPPORT: Provide students with options to choose from for their expected outcome. Students choose the one that they think will be true and record it on their sheets. For example, if the testable question is about relating the strength of a push to the distance a car travels, the options might be something like: ○ We expect that if more force is used to push the car, the car will move further. ○ We expect that if more force is used to push the car, the car will travel less far.
6. Data & Observations:	● LEAST SUPPORT: Provide students with the blank handout. ● Engage in a whole-class discussion (if students are all doing the same investigation) or small-group discussions (if students are doing different investigations) ahead of time to ensure that students will know what and when to observe during their experiment and how they will record that information on the sheet. ● MOST SUPPORT: Set up the investigation as a demonstration that you perform with student assistance. Have students measure and record data and observations as you go.
7. What did your investigation reveal?	● LEAST SUPPORT: Provide students with the blank handout. ● Direct students back to the testable question and expected outcome sections to see if those answers can support their work in this section. ● MOST SUPPORT: Engage in a whole-class discussion (if students are all doing the same investigation) or small-group discussions (if students are doing different investigations).
8. What new questions did this bring up?	● LEAST SUPPORT: Provide students with the blank handout. ● If you recorded questions earlier in this lesson or earlier in the unit, students may refer back to these lists to see if they have new questions or new answers. This may also lead to new ideas for further investigations. ● If you recorded questions earlier in this lesson or earlier in the unit, revisit these questions in whole-class discussion to see if students have new questions to add, new ideas for investigations, or ideas about the questions previously asked. ● MOST SUPPORT: Engage in a whole-class discussion (if students are all doing the same investigation) or small-group discussions (if students are doing different investigations).

After The Investigation (Student Metacognition Prompts)

Consider using one or more of these prompts with students (or creating your own!) after each time they plan and carry out their investigations. If they can revisit these ideas before their next experience, it might support their progress at this Science and Engineering Practice!

- When planning and carrying out investigations, I learned to pay attention to…
- When planning and carrying out investigations, I learned to consider…
- Next time I am asked to plan an investigation, something I want to remember is…
- Next time I am asked to plan an investigation, something I want to do differently is…
- The most difficult part of planning and carrying out an investigation is…
- The best part about planning and carrying out an investigation is…

Example Seed Choices

Image	Name	Cultural & Local Relevance	Notes
	Devil's Club	"Important medicinal plant for many Indigenous communities in western North America."[1]	Experiment on the ISS! As part of a science project on the plant, Devil's club seeds were sent to the ISS in late 2022. Astronauts worked on the plant experiment and germinated Devil's club seeds to compare them to a similar plant of the same species on Earth.
	Lima beans	"The lima bean has been a cultivated crop of the indigenous Peruvians for nearly 9,000 years"[2]	Germinate and sprout in just 7 to 10 days.
	Pinto beans	"Beans held immense cultural and symbolic significance in Mesoamerican civilizations."[3]	Grab a resealable plastic bag and a moist paper towel. Fold a paper towel into square quarters, place a bean in the inner fold, gently place the paper towel and bean in the bag and seal the bag. Label each bag and tape them to a window that receives adequate sunlight. Make observations every 2-3 days
	Thale Cress (Arabidopsis thaliana)	"A. thaliana is a central genetic model and universal reference organism in plant and crop science."[4]	"Arabidopsis has been grown on the International Space Station and first flowered in 1982 aboard Soviet Salyut 7. Arabidopsis is critical to spaceflight plant biology research."[5]

	Herbs like basil, mint, sage, thyme, rosemary, or oregano	• The History of Basil • JSTOR: Mint • Sage • Rosemary	Herbs require very little maintenance and germinate and grow quickly. Growing a class herb garden may be a good project. Teams of 2-3 students could be in charge of conducting experiments to find the best growing conditions for a specific herb they are assigned.
	Cempasúchil (Marigold)	Cempasúchil are the iconic flowers of Día de los Muertos (Day of the Dead).	Germinate in five to 10 days. Science experiment examples: • Marigold experiment • Merry marigolds • 5th grade marigolds
	Sunflower	"Native to North America, sunflowers were widely cultivated by indigenous peoples for their edible seeds and various other uses like medicine, dyes, or oil." [6]	"In 2012, astronaut Don Pettit grew several plants (including a sunflower) in plastic baggies he'd brought on board as a personal science experiment."[7]
	Wapato	"Eaten by many indigenous groups throughout Washington and Oregon. Wapato was as important to the Yakama diet as other sacred foods like salmon or huckleberries."[8]	

Agricultural Plan Claim Examples (TEACHER GUIDANCE ONLY)

These examples are provided to guide the teacher NOT THE STUDENTS. Use these examples to help guide students to their investigation plan as well as their agricultural plan.

Claim:

- Example: If astronauts follow our agricultural plan to grow ## plants of _______, they will be able to produce ## calories of food per day.
- Example: It will take astronauts ## liters of water in order to produce this amount of food per day.

Evidence: Provide raw data with charts or tables, as well as explanations.

- Example: In our experiment, 1 lettuce plant produced 100 calories of lettuce in 50 days.
- Example: In our experiment, we used ## mL of water per day for ## days to water the plant.
- Example: In this (article/video) from NASA, we found that _________________________.

Calculations: Show the math and explain your calculations.

- Our lettuce plant grew 100 calories in 50 days. That is 2 calories per day.
- If astronauts start growing 2 plants each day (so that they are ready at different times), they then can harvest two plants of lettuce or 200 total calories of lettuce every day starting after 50 days (when the first plants mature).

Assumptions:

- Example: We assume that the difference in gravity between Earth and the Moon will not impact the results of our plant experiment.
- Example: We assume that the seeds that astronauts take to the Moon won't be affected by space travel.
- Example: We assume that the astronauts will use seeds and soil like the ones we used.

NASA Resources about Plants

Link	Grade(s)	Description
Our World: Systems to Grow Plants in Space	Best for grades 3-5	Video (05:44) cc available Describes the needs of plants and how NASA scientists and engineers are growing plants in space.
Space Food Systems	Best for grades 6-8	Images and text - 519 words; Video (1:40) Describes the work of the Space Food Systems Laboratory and shows astronauts preparing food.
Can we grow safe and nutritious food in space?	Best for grades 6-8	Images, graphs, text - 844 words Discusses growing red romaine lettuce in the VEGGIE growth chamber.
Mission Commander Thrives as 'Space Gardener'	Best for grades 6-8	Images and text - 525 words NASA explores new methods like plant transplants and seed films to enhance astronaut nutrition.
VEGGIE Fact Sheet	Best for grades 6-8	Text article with pictures-1977 words Talks about the VEGGIE system and growing red romaine lettuce in space
Growing Plants in Space - NASA	Best for grades 9-12	Text - 651 words Talks about the need to grow fresh produce in space for astronaut health and wellbeing. NASA is growing plants in space through VEGGIE, the Advanced Plant Habitat and BRIC-LED
NASA Teams Persevere Through Plant Challenges in Space	Best for grades 9-12	Text - 943 words NASA's VEG-05 experiment successfully grew tomatoes on the International Space Station, offering valuable insights into space farming.
Chickpeas grown in lunar regolith are stressed but reach maturity	Best for grades 9-12	Text- 621 words(If we are going to provide additional resources for this MO and require secondary students to cite at least one resource, this could be included.)
Season 5, Episode 26: How to Grow Food on the Moon	Best for grades 9-12	NASA podcast audio (20:35) Text - 1,499 words Dr. Anna-Lisa Paul explains her research growing plants in lunar soil.
So You Want to Be a Space Farmer…	Best for grades 9-12	Images and text - 847 words Researchers aboard the International Space Station experiment with growing various plants (mustard greens, lettuces, kale, pak choi, Chinese cabbage, zinnias, peppers, and soybeans).