Worlds Apart
REMOTE SENSING OF MARS

PLANETS

Science Pathway

Planetary Science Activities for Out-of-School Time • Grades 6–8

Contents

Welcome to Worlds Apart!

In this unit, learners think and work like scientists and engineers. They investigate and use real NASA data about Mars to select a scientifically interesting landing site and design remote sensing devices.

The unit is composed of a Science Pathway and an Engineering Pathway. In both pathways, learners have the opportunity to build their problem solving, teamwork, communication, and creative thinking skills. Specifically, these units are designed to ensure that learners will

- engage in real-world activities that provide inclusive ways for all learners to connect to science and engineering.
- choose their path through open-ended challenges that have multiple solutions.
- engage in the habits of mind of engineers and inquiry practices of scientists.
- communicate and collaborate in innovative, active problem solving.

Note
Much of the information at the start of this guide is the same for the Science and Engineering Pathways. If you have already read the Engineering Pathway, you can read just *Learners Working and Thinking Like Scientists*, p. X, and the *Science Pathway Storyline*, pp. X–Y, then skip to the *Science Pathway Vocabulary*, pp. X–Y, and read from there.

Getting to Know PLANETS

Planetary Learning that Advances the Nexus of Engineering, Technology, and Science (*PLANETS*) is an interdisciplinary and cross-institutional partnership that integrates planetary science, education, technology, and engineering.

The Center for Science Teaching and Learning at Northern Arizona University (NAU), the U.S. Geological Survey (USGS) Astrogeology Science Center, the Museum of Science, Boston, and WestEd have partnered to develop, pilot, and research the impact of three curriculum units and related professional development resources (http://planets-stem.org) for grades 3–8.

The purpose of *PLANETS* is to increase public awareness and use of NASA resources by highlighting the relationship between science, technology, engineering, and mathematics in the context of planetary science in out-of-school time settings.

Worlds Apart Unit Overview

Remote sensing engineering is an interdisciplinary field that deals with the collection of data remotely, or from a distance. It has a wide variety of applications, from creating models of cities or natural landscapes to helping scientists predict the effects of climate change to precisely tracking orbiting satellites. In this unit, learners engineer remote sensing devices and analyze remote sensing data from Mars to choose a landing site for a rover. The unit contains an Engineering Pathway and a Science Pathway.

A video playlist for the complete unit is available on the website.

Engineering Pathway Overview: Engineering Remote Sensing Devices

Remote sensing engineers use techniques from many fields, such as cartography, optics, civil engineering, software engineering, and computer science.

Learners in the Engineering Pathway are part of a team on a fictional NASA mission. They engineer remote sensing devices to gather and visualize information about the surface of Mars. The data they collect will help the scientists meet their scientific goals, such as choosing a landing site that is best suited for gathering data on the geological features of the landscape and looking for evidence of water.

The Engineering Pathway Storyline that more fully articulates the progression of activities can be found on pp. X–Y of the Engineering Educator Guide.

Science Pathway Overview: Remote Sensing of Mars

Planetary scientists often use the technologies developed by remote sensing engineers to further their understanding of the planets, satellites, and smaller bodies in the solar system. Engaging in the study of other planets provides scientific insight into the origins of features on Earth.

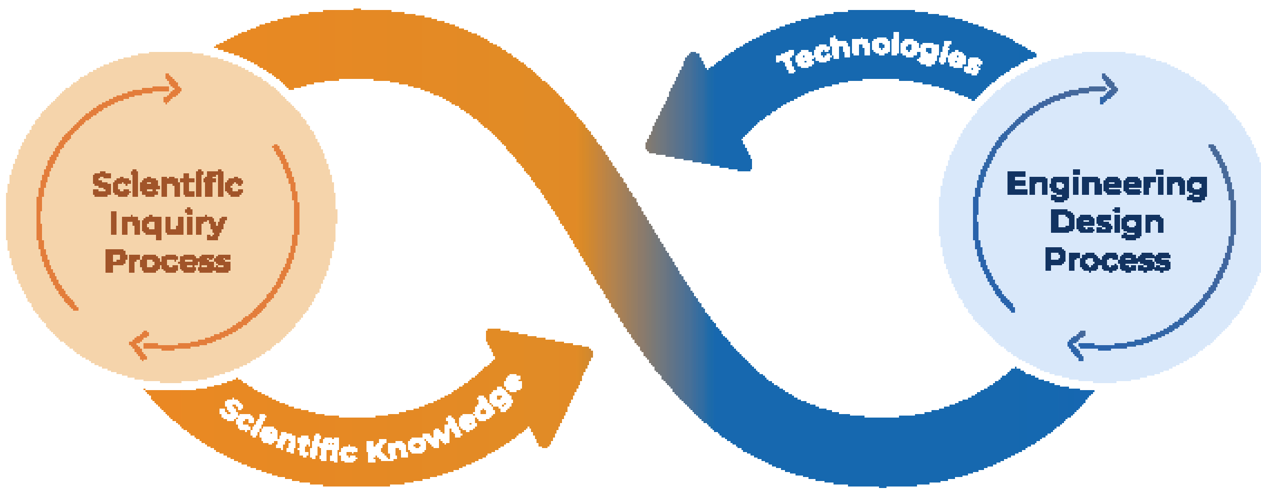
Learners in the Science Pathway (this guide) participate in a fictional NASA mission to choose a landing site for a Mars rover. Learners engage with and interpret Mars data captured during actual NASA missions. In these activities, learners learn about the data obtained by remote sensing tools and techniques developed by engineers. They explore how planetary scientists use data from these technologies to understand habitable environments on Mars and how the planet has changed over geologic time.

The Science Pathway Storyline that more fully articulates the progression of activities can be found on pp. X–Y of this guide.

Connecting Across Science and Engineering

Science and engineering depend on one another. Engineers leverage their scientific knowledge to effectively and efficiently develop new technologies. Scientists rely on a wealth of technologies that have been developed by engineers to advance our understanding of the natural world—and their understanding, in turn, helps engineers develop additional technologies.

Scientific inquiry and engineering design require similar skills and practices, such as bringing a lens of curiosity, taking a systems approach, and tapping into creativity to answer questions and solve problems. Both processes do not follow a set path. Both draw on lived experiences and direct observation, then translate the knowledge gained into inquiry and teaching. And both engage thinkers in using tools like models, mathematics, and computers.



Finding equitable opportunities to engage learners in the habits of mind of engineers and the thinking practices of scientists can increase engagement and catalyze STEM identity and confidence for all learners.

Learning activities that engage learners in the habits of mind and thinking practices of engineers and scientists also fuel development in the 21st Century learning skills of critical thinking, creativity, collaboration, and communication. For more insight into how these skills develop as learners engage in an engineering design process, see the educator resource on [Developing 21st Century Skills](#).

Learners Working and Thinking Like Scientists

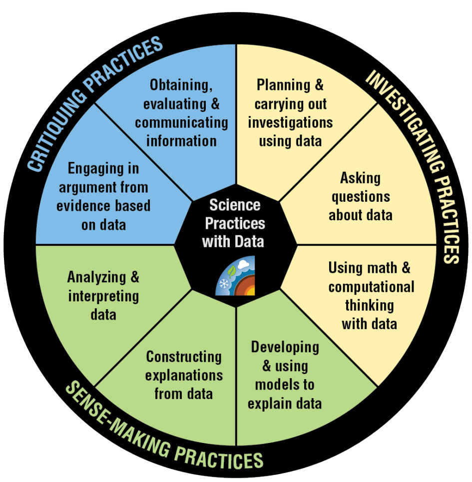
A Process of Scientific Inquiry

Like an engineering design process, scientific inquiry is a non-linear and iterative process of investigating, reasoning, evaluating data and models, and critiquing and communicating explanations based on evidence. During this process, scientists rely on mathematics, computers, and technologies that have been developed by engineers.

Science Practices

As scientists engage in the process of inquiry about and with natural phenomena, a few practices emerge from their work. These are known as practices instead of “skills” because they require a coordination between both knowledge and skill. The core practices that learners should engage in as they move iteratively through scientific investigations, reasoning, and critiquing are provided below. You’ll notice that many science practices are similar to the habits of mind that engineers use—such as asking questions, using mathematics, and developing models. These practices include

- Asking questions
- Planning and conducting investigations
- Using mathematics and technology
- Developing and using models
- Analyzing and interpreting data
- Constructing explanations
- Engaging in argument from evidence
- Finding, critiquing, and communicating scientific information



Graphics adapted from My NASA Data, “Resources for Science and Engineering Practices (with Data)”

Navigating the Unit

Considerations for Using the Worlds Apart Unit

- The following pathways present suggested orders in which to teach the activities. However, you can adapt the order of activities as appropriate for your learners and setting. (For example, you can alternate between pathways.)
- If you have time, it is beneficial for learners to engage in both the Engineering Pathway and then the Science Pathway. Learners do not need to repeat the context-setting.
- It is not necessary for learners to complete the Engineering Pathway activities to participate in the Science Pathway.

For additional resources, please see the website.

CONTEXT SETTING ACTIVITY: Ready, S.E.T., Go!

Learners investigate remote sensing. As scientists, they decide what they want to learn about a planetary body. As engineers, they choose which instruments to put on a spacecraft for that investigation.

Engineering Pathway

ACTIVITY 1: Investigating Light

Learners investigate how light travels and how mirrors can redirect it to gather data from a distance.

ACTIVITY 2: Redirecting Light

Learners design light redirection systems to gather data from a distance.

ACTIVITY 3: Finding Minerals

Learners work to distinguish between minerals using sight and/or sound.

ACTIVITY 4: Finding the Shape of Land

Learners engineer a model of a LiDAR technology to capture the shape and height of a landscape (topography).

ACTIVITY 5: Creating a Remote Sensing Device

Learners work in groups to plan, create, and test remote sensing technologies that use the different technologies from the previous activities to gather data from a distance.

ACTIVITY 6: Improving a Remote Sensing Device

Learners improve their remote sensing devices by making them easier to use, more compact, or better able to gather high-quality data.

ACTIVITY 7: Preparing for the Engineering Share-Out

Learners plan to share their designs at an Engineering Share-Out.

ACTIVITY 8: Engineering Share-Out

Learners recommend a remote sensing technology to be sent on a spacecraft.

Science Pathway

ACTIVITY 1: Introducing Landforms

Learners explore how different landforms are formed by wind and water.

ACTIVITY 2: Exploring Landforms on Mars

Learners examine images of landforms on Mars and Earth to find evidence of past water.

ACTIVITY 3: Introducing Topography

Learners build three-dimensional models of topographic maps and then turn them into two-dimensional maps.

ACTIVITY 4: Exploring Topography on Mars

Learners interpret topographic maps of Mars to identify safe and interesting landing sites.

ACTIVITY 5: Introducing Spectroscopy

Learners learn to interpret the spectra of reflected light from various objects.

ACTIVITY 6: Using Spectroscopy to Understand Mars

Learners interpret spectra to identify water-based minerals at potential Mars landing sites.

ACTIVITY 7: Choosing a Landing Site and Preparing for Science Share-Out

Learners combine multiple data sets made possible by technologies that engineers designed to choose a safe and scientifically interesting landing site for a Mars rover. They then prepare to share their findings with the whole group and invited guests.

ACTIVITY 8: Science Share-Out

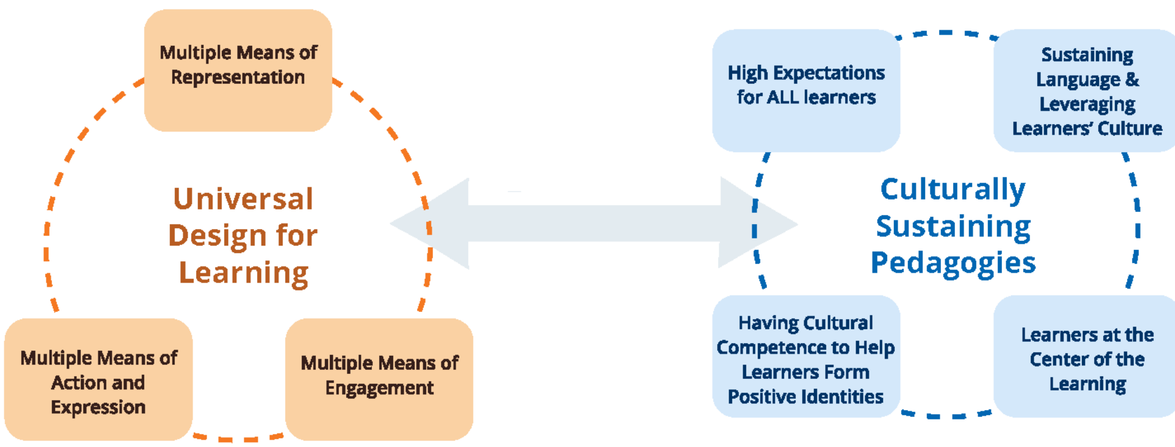
Learners share their recommendations for the safest and most scientifically interesting Mars rover landing site.

Educator Resources to Support Learning

An Inclusive and Equitable Approach for STEM Learning

The Worlds Apart unit has been designed with an explicit focus on promoting STEM learning for all, and particularly Indigenous learners, emergent multilingual learners, and learners experiencing differing physical and/or sensory abilities. The Universal Design for Learning (UDL) and culturally sustaining pedagogies (CSP) conceptual frameworks informed the instructional design of this unit. This purposeful design supports all learners by reducing as many barriers as possible and incorporating planning for variability in learner strengths, needs, and interests.

These principles include the following:



Creating Inclusive & Collaborative Learning Environments

To create an inclusive learning environment, educators need to approach their learners with an asset-based mindset. Each learner possesses assets that contribute to the development and maintenance of that person's identity. Assets can be intellectual, physical, or social skills and personal strengths or qualities. A few ideas for cultivating inclusive and cooperative learning environments include the following:

Practices & Strategies for Inclusive Learning Environments

Engaging All Learners 	● Facilitate inclusive and cooperative learning environments. ● Build relationships with learners and their communities for learning partnerships. ● Build rapport to establish an emotional connection. ● Affirm the personhood of each learner by appreciating all aspects that they bring into a learning space and creating accessible and inclusive learning spaces. ● Design learning experiences that are authentic and relevant to the contexts of learners. ● Incorporate multisensory instruction. ● Provide options for multiple forms of expression to demonstrate understanding. ● Model and support self-advocacy.

The Engaging All Learners icon appears in tips that support inclusive learning environments.

Designing Instruction to Reach Diverse Learners

The strategies outlined below appear in this unit to support three groups of learners:

- **Multilingual learners:** Youth who speak languages other than English at home and are in the process of becoming fluent speakers of English.
- **Indigenous learners:** Youth who descend from the original, culturally distinct ethnic peoples of a land.
- **Learners with diverse abilities:** Youth who experience differing physical abilities: (a) physical traits that affect mobility and/or dexterity; (b) sensory abilities that affect sight; and (c) sensory abilities that affect hearing.

Some of these strategies, initially designed and highlighted below for specific learners, have shown potential benefits for all learners. These strategies have been adapted from the *PLANETS Practical Guide for Inclusive and Engaging STEM Learning: Promoting Inclusion and Engagement in STEM Learning: A Practical Guide for Out-of-School-Time Professionals*. The icons shown below appear throughout this guide in tips that are especially relevant for each group of learners.

Strategies for Multilingual Learners

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
Encourage *translanguaging*: learners using all the languages they know and making connections between those languages.	Translanguaging signals to multilingual learners that their languages, culture, and experiences are valued and enrich learning. It empowers learners to participate and can increase their comprehension and engagement. Note that not all words have exact counterparts in English.	Encourage learners to share key vocabulary in their home or preferred languages. You can capture terms visually. Note that some learners, including many Indigenous ones, communicate through gestures instead of speech.	See Promising Instructional Practices, section 3: "Encourage Translanguaging and Storytelling" on p. 20 of the *Practical Guide*.
Provide multiple means of accessing language.	Providing learners enough support and tools (e.g., images, videos, diagrams with headings) to understand texts on their own empowers them to independently make sense of content without compromising the complexity of language. Instead of simplifying language, amplify speech and text with supports and offer	Actively listen to learners' discussions during group activities and have them use wall posters to make sense of key vocabulary in each activity. Use icons and images to anchor language.	See Promising Practices for Program Design, section 1, "Welcoming Learning Environments" on p. 13 of the *Practical Guide*.

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
	assistance to help learners grasp concepts effectively.		
Teach vocabulary in context.	Exposing learners to vocabulary and concepts together and not separately helps learners make sense of key concepts and ideas.	Learners engage in activities and then use their experiences to make sense of vocabulary.	See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on p. 13 of the *Practical Guide*.
Provide multiple means of expressing ideas.	Multiple forms of expression, such as spoken, visual, and written, help learners share their understanding of science and engineering, make sense of concepts, and clarify their ideas. Offering space to use different levels of formality (e.g., casual language from home vs. academic language from school) helps learners make sense of ideas.	Share-outs during group activities encourage multiple means of expression. Learners can share in diverse ways (e.g., posters, graphs, writing, drawings, audio, gestures, or videos). Rather than "correcting" learners' speech, help them connect less-formal and more-formal words with similar meanings.	See Promising Curriculum Design Elements, section 3, "Provide options for multiple forms of expression to demonstrate understanding" on p. 28 of the *Practical Guide*.
Use strategic grouping.	Conversations among peers who share languages (e.g., pairs, small groups, or whole-group share-out) provide a safe environment for learners to participate	Activities engage learners in peer-to-peer conversations and sense-making discussions, including in pairs, small groups, and the whole group, depending on the	See Promising Instructional Practices, section 1, "Facilitate inclusive and cooperative learning environments" on p. 16 of the *Practical Guide*.

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
	and gain comfort and confidence while testing out ideas. Educators can then build on the ideas expressed in whole-group discussions.	needs of the learners.	
Prioritize precise name pronunciation and understanding.	Names are important in culture and personal identity. Pronouncing names correctly shows respect for individuals and their culture. (Because different languages use different sounds, it can take practice to pronounce names correctly.) This approach is particularly beneficial for multilingual learners but creates an inclusive environment for all learners.	When meeting new learners, educators are encouraged to ask about, practice, and model pronouncing learners' names correctly.	See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on p. 13 of the *Practical Guide*.

Strategies for Indigenous Learners

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
Encourage narratives.	Indigenous communities have strong narrative traditions. These traditions serve as vital conduits of cultural heritage, transmitting knowledge, values, and history across generations. Through oral narratives, these communities forge a profound connection to their ancestral roots, fostering a sense of identity. Relating narratives lets learners receive stories and tell their own. Narratives can be spoken, written, in song, or in pictures.	Make time for learner narratives that connect their learning to existing knowledge, stories, and culture. The "Building Community and Family Connections" section on p. X offers extension activities to engage community and family. Take time to understand how stories are told in a particular community. Rhetorical style and the expected parts of a narrative vary between groups.	See Promising Instructional Practices, section 3: "Encourage Translanguaging and Storytelling" on p. 20 of the *Practical Guide*.
Use strategic grouping.	Collaborative decision-making is more effective than individual spotlights in some Indigenous cultures. Small-group rather than large-group work enhances communication for Indigenous learners. Thoughtful talk is often valued over spontaneous contributions, and delayed engagement	Group work is built into each activity. Grouping suggestions provide a comfortable group setting for Indigenous learners and others, such as grouping learners in even numbers to avoid a single designated leader.	See Promising Instructional Practices, section 1, "Facilitate inclusive and cooperative learning environments" on p. 16 of the *Practical Guide*.

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
	may signify politeness rather than disinterest or shyness.		
Prioritize precise name pronunciation and understanding.	Names are important in culture and personal identity. Pronouncing names correctly shows respect for individuals and their culture. (Because different languages use different sounds, it can take practice to pronounce names correctly.) Note that Indigenous learners may want to share other information, such as their connections to tribes and locations.	When meeting new learners, educators are encouraged to ask about, practice, and model pronouncing learners' names correctly.	See Promising Practices for Program Design, section 1, "Features of Culturally and Linguistically Accessible and Welcoming Learning Environments" on p. 13 of the *Practical Guide*.
Design authentic and relevant learning experiences.	Learners are most engaged when what they are learning is connected to their lives and communities. Providing a relevant cultural context helps to drive this engagement.	Spend time in learners' community and make connections with local knowledge keepers. Learn about the cultural approaches of the community regarding competition and collaboration, communication styles, and systems of observation.	See Promising Curriculum Design Elements, section 1, "Design learning experiences that are authentic and relevant to the contexts of learners" on p. 23 of the *Practical Guide*.

Strategies for Learners with Diverse Abilities

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
Ask learners what they need.	The needs of learners with diverse sensory and physical abilities vary. Learners and caregivers, being the most knowledgeable about their capabilities, provide valuable insights. Educators should emphasize learners' strengths and rely on them to guide facilitation of activities.	Ask learners directly about their needs prior to beginning an activity. This guide gives some ideas to consider when offering learners options. Learn about etiquette for working with blind learners, etiquette for working with d/Deaf learners, or etiquette for working with wheelchair users.	See Promising Practices for Program Design, section 1, "Create safe, accessible, and welcoming learning environments" on p. 11 of the *Practical Guide*.
Incorporate multisensory activities.	Visual representations can be particularly beneficial for learners who are deaf or hard-of-hearing. Visual science and engineering models are powerful tools to illustrate observations, processes, and connections. Auditory modalities of instruction can facilitate access to learners who are blind or have low vision. Tactile models and physical objects are	Learners are given diverse means to participate in activities. For instance, spectrographic information is presented both visually and aurally so that all learners can access it. Allow blind and low-vision learners to explore pre-made	See Promising Curriculum Design Elements, section 2, "Incorporate multisensory instruction" on p. 26 of the *Practical Guide*.

Strategy	Why is this important?	Strategy in Action	Connections to the PLANETS Practical Guide
	beneficial for all learners but are particularly important for blind and low vision learners.	models ahead of time and to join the educator during demonstrations to follow the educator's movements.	
Use strategic grouping.	For blind and low vision learners, although a note-taking role may be a preferred option, provide learners with the flexibility and opportunity to choose from a variety of roles, fostering exploration and skill development. For deaf and hard-of-hearing learners, group work can be challenging due to elevated noise levels. Engage learners in smaller groups, move groups to quieter spaces, and encourage learners to speak clearly so everyone can follow the conversation.	Educators are provided with guidance on surfacing learners' diverse abilities through activities. It's essential to ask individual learners about their preferences and needs, as learners with diverse abilities have widely varying preferences. Consider designating partners to ensure supportive groupings.	See Promising Instructional Practices, section 1, "Facilitate inclusive and cooperative learning environments" on p. 16 of the *Practical Guide*.

To read *Promoting Inclusion and Engagement in STEM Learning: A Practical Guide for OST Professionals*, please see https://planets-stem.org/ost-practitioner-guide/.

Building Community and Family Connections

Strong relationships are key to learner success. Building community and family connections with learners encompasses having ongoing and meaningful two-way interactions between educators and families and/or other communities of supportive adults. It also involves creating a learning environment within OST (Out-of-School Time) programs that is familial, supportive, and empowering. OST programs with strong learning environments and communities recognize the assets that learners bring and allow learners to express themselves, making them feel comfortable engaging in STEM content. Family connections set the stage for social-emotional learning in the unit via

- Relevance—Family connections allow learners to draw connections between NASA science and engineering and the science and engineering in their daily lives and communities. This type of connection allows learners to bring their own funds of knowledge to the activities.
- Belonging—When learners see how their cultures and families use science and engineering principles, they feel that they belong in STEM.
- Cultural responsiveness—Family connections allow for relevant aspects of learners' cultures to enter or ground the learning in ways that the educator may not have been aware of. Learners' cultural knowledge can play an important scaffolding role in learning science and engineering while simultaneously sustaining that cultural knowledge for the next generation.

What does building community and connections look like in action? A few examples of how to purposefully develop these relationships with learners and their families include the following:

- **Use a variety of communication methods.**
- **Acknowledge challenges to family and community engagement.**
- **Invite families to engage in and design STEM learning activities.**

Consider using some of the following ways to build family connections during this unit based on your capacity and/or your learners' ability to include family members:

- Add an activity in which you invite families to be guest speakers. (Families can also work with you to find guest speakers from the community.)
- A Level Up! tip at the end of each activity invites learners to discuss a particular question with their families. (You can also suggest family activities to spark conversation around a particular topic.) Learners can share what they discussed at the start of the next activity.

- Invite families to the Engineering and Science Share-Outs at the end of each pathway to not only share in celebration of their learners' accomplishments but also to provide their knowledge (cultural or otherwise) about the engineering or science discussed and used in the pathway.

Instructional Support Tips for Learning

Within each activity across the Remote Sensing unit, several strategic tips are provided as opportunities for additional instructional support. These tips are guided by the PLANETS core design principles described earlier.

- Support Thinking
- Teaching Tip
- Connecting Across Activities
- Support Learner Differences
- Level Up

The table below provides guidance on the purpose and use of each of the tips found within the activities.

Instructional Support Tip	**Purpose**
Support Thinking	Provides ideas for educators to productively support learners' thinking, such as • suggestions of targeted language to use with learners to increase social emotional supports. • things to emphasize during student collaboration. • language that explicitly helps students to realize they are working, thinking, and looking like engineers or scientists (metacognitive and representation/identity/confidence in STEM).

Instructional Support Tip	Purpose
	• additional resources that may enhance student engagement/thinking about the current instructions of the activity (e.g., videos, audio).
Teaching Tip	Provides additional recommendations for educators with regards to the mechanics of the activity, such as • modifying materials. • grouping and/or roles of learners during parts of the activity based on materials, timing, and engagement. • additional procedural tips to increase effectiveness of investigations and designs. • modifying timing of activities with different procedures.
Connecting Across Activities	Highlights ways that the activities connect within the pathways and across the disciplines of engineering and science.
Support Learner Differences	Provides just-in-time supports during the activity that help educators ensure they are meeting the needs of all STEM learners—especially Indigenous learners, emergent multilingual learners, and learners with diverse abilities—such as • ways to support multiple pathways for ensuring all learners can equitably engage in the activity.

<table>
<tr><th>Instructional Support Tip</th><th>Purpose</th></tr>
<tr><td></td><td>strategic peer grouping(s) to enhance engagement equity.
additional challenges or ways to increase the learning rigor for learners who are ready.
additional resources that increase equity to ensure that all learners can engage effectively in the activity (e.g., videos, audio).</td></tr>
<tr><td>Level Up</td><td>Provides supplemental guidance to educators facilitating activities, such as
Ways to make the activities more inclusive to all STEM learners.
Extensions to broaden both content and options provided within each activity. Note that time estimates for Level Up activities are provided separately from the main activity timing.</td></tr>
</table>

References

Elsayed, R., Clark, J. G., Daehler, K. R., & Bloom, N. E. (2022). *A practical guide for out-of-school-time professionals to promote inclusion and engagement in STEM learning*. PLANETS, Northern Arizona University and WestEd.

Inclusion Activities

At the beginning of each activity, you can lead an inclusion activity that is appropriate for your group and relevant to the communities they belong to. Below are some possible activities:

Story of Your Name

In pairs or small groups, have learners share their names and stories behind them. For example, what do they mean? Why were they given? Have learners share other important information about their identities, such as locations they are from and tribes or other groups they belong to.

Handshakes and High Fives

Play three rounds of this inclusion activity. Each round, have learners pair up and introduce themselves in some way (e.g., handshake, high five, elbow bump, dance, nod, codeword). Then ask a question and have them discuss it for one minute. Once learners have completed all three rounds, have them re-find their three partners in order and repeat the introduction for each.

Paper Toss

Give each learner a piece of paper and a writing utensil. Ask a question and have them write an answer on the paper (for example, What is your name? What do you do for fun?) Have learners crumple the papers and throw them around. Then have them uncrumple the papers and share the answers with the group.

Choose an Object

Lay out a set of objects, such as small figurines, playing cards, or craft supplies. You can also have learners bring their own objects. Ensure that the objects are interesting to touch and at least some of them make noise. Ask a question (for example, How is your day going? What is a strength you bring to the group?) and have each learner pick up an object that represents their answer (for example, *I chose the owl because I am good at watching what is happening*). Have learners share their objects and answers in pairs or small groups.

Interviews

Have learners pair up and spend three minutes each interviewing each other, then have them share about their partners in a large group. Possible interview questions include the following:

- What is your favorite place to hang out that is not school or home?
- What are some things you are good at?
- What tools or machines do you know how to use?
- What languages do you speak at home?
- What is something you did this week with someone else?

- How do you like to express yourself?

Accessibility Check

Have learners go around a circle and share their names and access needs. Access needs are things they might need to fully participate and feel comfortable in an activity or space. They can be anything that helps people learn, communicate, move around, or feel safe and included. As needed, share first yourself and give some examples, such as “I need short breaks during long activities to stay focused,” “I need to refill my cup of water,” “I feel more comfortable lying on the floor,” or “I need pictures to help me understand what we are learning.” Learners can also say “I’m still thinking about my access needs” or “All my access needs are met, check.” Note that learners may not be comfortable sharing their needs until after several days of participation.

Design a NASA Mission Patch

NASA mission patches are special symbols that tell the story of each space mission. They use pictures, colors, and symbols to show the mission's goals, who the astronauts are, and important parts of the crew’s lives. Have learners form groups of three, choose a mission name, choose a patch shape, and draw or write three things to include on their patch. Patches can include meaningful images, symbols, and colors. As needed, show examples from NASA’s Human Spaceflight Mission Patches.

Transition

Say: **Let's talk about why we did this. Inclusion isn't just a nice idea–it's crucial for success, both here and in the real world. At NASA, every astronaut needs to know their team well. Why? Because in space, your crew is your lifeline. Similarly, in our group, everyone matters. We learn better when we understand each other. Knowing our teammates helps us work together and solve problems. By sharing parts of ourselves, we build trust and respect. This makes our “mission”–learning together–more fun and more effective. Remember, great teams are built on understanding and appreciating each person's unique strengths.**

Conclude by connecting the inclusion activity to what learners are doing next. For example, say: **You just made different partners. Now you are going to work with one of those partners to…**

Intentional Grouping Strategies

Intentional Grouping can support learners in a variety of ways.

Group roles can play to learners' diverse abilities and strengths. For instance, a blind or low vision learner might be much more skilled at tactile or auditory tasks, and having a role that plays to this strength will elevate that learner and strengthen the group. Never assume which tasks learners will prefer, because they can feel othered and misunderstood. Give them the first choice of group roles.

Grouping learners with similar spoken or signed languages can help multilingual learners bounce ideas off each other in their native language before translating them for the whole group. This will also help learners decide what words to share in their native languages.

Grouping learners by culture can allow them to work through things in ways that are familiar and valued at home before sharing with the larger group. For instance, Indigenous learners might benefit from being grouped together and working by consensus rather than by having a leader. Or they may decide to communicate their final challenge on posters during a gallery walk, rather than by presenting publicly.

Similarly, if learners are grouped by shared interests or hobbies, they may start to interpret the learning in the context of what they know, which is fantastic! For example, "We mitigate hazards when biking all the time by slowing down, wearing helmets, and not biking when it's dark outside."

The number of learners in a group

Groups of 2: If students are sharing personal information or stories, working in pairs first gives learners an opportunity to hear other ideas and rehearse their own ideas before sharing with the whole group. Pairing up is especially helpful for multilingual learners.

Groups of 4: Use groups of four when learners would benefit from lots of perspectives or ideas.

Please note, these activities are not designed for groups of five or more. A group of five will likely have an outlier with not enough to contribute.

Science Pathway Storyline

Science Activities 1–6

Learners gain knowledge about data collected from remote sensing technologies designed by engineers so they are successful in making their recommendations for a Mars landing site in the final activity.

Science Activities 7–8

Learners combine the data across the prior activities to select a safe and scientifically interesting landing site for a Mars rover. They then share their recommendations.

[Educator Previews here.]

Science Pathway Vocabulary

This list is included to provide an overview of the content of this pathway. Note that you should not pre-teach it to learners before the activities–terms are introduced after learners have direct experience with the materials and processes to which those terms are connected.

Ready, S.E.T., Go!

- **Composition:** What a surface is made of
- **Constraints:** limits on a design
- **Criteria:** things a successful design needs to do or have
- **Fairing:** The part that sits on top of the rocket and protects a spacecraft during launch
- **Physical properties:** The shape and texture of a surface
- **Resolution:** The amount of detail in an image
- **Technology:** an object, system, or process designed by people to solve a problem

Science Activity 1

- **CTX:** Context Camera, a camera on the Mars Reconnaissance Orbiter
- **HiRISE:** High Resolution Imaging Science Experiment, a camera on the Mars Reconnaissance Orbiter
- **Landform:** a shape on the surface of a planetary body

Science Activity 3

- **Topography:** the shape of land in an area
- **Topographic map:** a representation of the shape of land in an area

Science Activity 5

- **Spectrometer:** a technology that measures the amount of light reflected from an object at many different colors (wavelengths).
- **Spectroscopy:** the study of how light of different colors behaves when it touches something
- **Spectrum:** a range of colors

Teaching Tip
No new vocabulary terms are introduced in Activities 2, 4, and 6–8.

Science Materials List

The quantities below are for a group of 24 learners.

Non-Consumable Items

Quantity	Material
3	baking (cookie) sheets with raised rims
3 cups	gravel or pebbles
3	jugs, bottles, or watering cans, for refilling
3	pans or boxes, 9″ × 13″ (approx. 23 cm × 33 cm), such as dish pans, aluminum baking pans, or copy-paper box lids lined with plastic
3–6	rocks, large, dry
6	audio player(s) with headphones (or learners' personal devices)
6	drop cloths, tarps, or large trash bags (if working inside)
6	paper clips or small resealable bags (optional)
6 pairs	scissors
12 pairs	safety glasses
	rocks and minerals, assorted, small, such as gravel mixture
1	computer with internet access (optional)

Consumable Items

Quantity	Material
1 pad	chart paper
3	bags, trash (clear if possible)
3	cups, paper, 8 oz
3	pieces cardboard wrapped with aluminum foil with small notch cut (alluvial fan barrier; see Activity 1)
6 sheets	craft foam
6 sheets	felt, 9″ × 12″
6 rolls	tape, masking
6	glue sticks (optional)
6 sets	writing utensils (pencils or crayons), colored, in gradually darker shades of yellow, green, and blue if possible
10.5 cups	sand, completely dry
24	straws, regular
48	cleaning wipes (2 per learner, to clean safety glasses and headphones between users)
24	face masks
24	Science Notebooks
	water
6	markers, dry-erase, fine point (optional, if using page protectors)

Quantity	Material
6	page protectors (optional)
24 pairs	gloves, plastic (optional)
	play-doh or clay (optional)
	school glue or puff paint (optional)
	sand or glitter (optional)

Science Advance Preparation

You can complete much of the preparation for the Science Activities ahead of time. Follow the steps below.

Level Up!
Consider whether you want to use the basic version of this pathway, which examines two sites on Mars (Gale Crater and Jezero Crater) or the advanced version, which adds two additional sites (Nili Fossae and Iani Chaos). The advanced pathway is more interesting and enriching with four choices, but it requires more time.

If you choose to use the advanced version, use the advanced versions of the following files:

- *Science Activity 2 Data Packet*
- *Science Activity 4 Data Packet*
- *Science Activity 6 Data Packet*
- *Mineral Station Signs*
- audio files

Educator Background

- Read through the entire PLANETS Science Pathway Educator Guide to learn more about the science content in this unit.
- Print and laminate any pages you want available for easy reference. (The Inclusion Activities, p. X, Intentional Grouping Strategies, p. X, and Pathway Storyline, p. X, are especially useful.)
- Print a copy of the Notebook for reference.
- Reflect on the learners who will engage in the pathway and identify ways to create an inclusive and collaborative learning environment (see pp. X–Y).

For the Whole Group

- Invite staff, family, and community members to attend the Science Share-Out in Activity 8. Make copies of the *Science Share-Out Invitation*, p. X, to distribute to family and friends.
- Prepare an *Our Ideas* poster by following the *Prep & Setup Guide*.
- Print the following handouts for stations:
    a. 6 copies of the *Landforms Handout*, in color, if possible

b. 3 copies of *Wind Station Directions*, p. X

c. 3 copies of *Water Station Directions*, p. X

d. 3 copies of each image in *Science Activity 6 Data Packet*

e. 3 copies of each image in *Science Activity 6 Data Packet*

f. 3 additional copies of Spectra Pages in *Science Activity 6 Data Packet* (if planning to make Tactile Spectra Models)

g. 6 copies of *Mineral Fingerprints Handout*

h. 6 additional copies of *Mineral Fingerprints Handout* (if planning to make Tactile Spectra Models)

i. 1 copy of *Mineral Station Signs* (3 signs per station)

- Print the images from the following handouts in 3D and/or swell paper if you are using this option:

  a. *Science Activity 2 Landforms on Mars Data Packet*

  b. *Science Activity 4 Mars Landing Site Topography Data Packet*

- Obtain or download topographic maps of your local area if you are using this option (see p. X).
- Make a sample topography model using the directions on Topography Template, p. X.
- Create a clay model of each of the landing sites in *Science Activity 4 Mars Landing Site Topography Data Packet* to provide a tactile version of the data (optional; see p. X). The models can be estimations; they do not need to be exact.
- Determine how you will share the Activity 5 and 6 audio files on the day of the activity with the whole group. You have the option to download the audio files or access audio files online.
- Prepare a tactile model by adding a line of glue or puff paint to the data line, to each of the axes, and on either side of the visible spectrum of each of the following graphs:

  a. 3 copies of *Red Paint,* p. X in the Science Notebook

  b. 3 copies of *Green paint,* p. X in the Science Notebook

  c. 3 copies of *Electromagnetic Spectrum*, p. X in the Science Notebook

  d. 3 copies of each graph in *Science Activity 6 Data Packet* (7 graphs)

  e. 6 copies of each graph in *Mineral Fingerprints Handout* (6 graphs)

Ensure you have a space to let the graphs dry. Consider sprinkling the glue with a bit of fine sand or glitter to add additional texture. Alternatively, print these on swell paper.

- To further support learners' understanding, it may be important to offer additional visual and audio support. Review the resources from the Activity Resources page and decide which you would like to have available.

Teaching Tip
If internet access may be a problem, consider downloading videos ahead of time. If it would benefit your learners, you can adjust the video playback speed. Note that video links may change over time; if a link does not work, try searching the title of the video.

Support Learner Differences

All videos in this unit include captions. As needed, these captions can be translated by online video platforms.

For Each Group of Learners

- Print 1 copy of each of the following handouts for each group of 4 learners:
    a. *Image of Mars Handout*, in color, if possible
    b. *Image of Mars in Context of the Solar System Handout*
    c. *Landforms Handout*, in color, if possible
    d. *Science Activity 2 Landforms on Mars Data Packet*, in color, if possible
    e. *Landing Site Ovals* on transparency or regular paper. Cut along the dotted lines to separate the ovals so there is one oval for each group of 2–4 learners. Cut around the oval to make individual ovals.
    f. *Topography Template*
    g. *Grand Canyon Topographic Map* or local map. See p. x
    h. *Grand Canyon Aerial Photo* or local photo. See p. x
    i. *Science Activity 4 Mars Landing Site Topography Data Packet*

i. Consider laminating the pages or placing them into plastic page protectors to prevent them from getting damaged.

For Each Learner

- Print and staple one Science Notebook for each learner, in color if possible.

Teaching Tip
If you think learners will benefit from having more space in the Notebook, print one-sided or add sheets of blank paper as you make the Notebooks.

Ready, S.E.T. (Science, Engineering, Technology), Go!

[When this activity is final, it will be copied from the Engineering Pathway.]

Science Activity 1: The Lay of the Land: Introducing Landforms

Educator Preview

Activity Snapshot

Learners explore how different landforms are formed by wind and water.

Timing	Prep Snapshot*	21st Century Skills Connection
Get Ready and Team Up 15 min Explore Landforms 20 min Reflect 10 min **Total 45 min** **Level Up Activities** 30 min each	Prep Time 60 min As needed, dry sand the day before. Set up Water and Wind Stations. Print resources. **See Materials & Preparation for full info*	● Critical Thinking **Science Practices** ● Developing & Using Models ● Analyzing & Interpreting Data

Guiding Question

What are landforms and how are they formed?

Learners Will Do

Explore how wind and water can create the same landforms on Earth and Mars.

Learners Will Know

Scientists examine landforms to learn about the past history and climate of a location.

Connecting Across Activities

Ready, S.E.T., Go!	Activity 1: Introducing Landforms	Activity 2: Exploring Landforms on Mars
Last time, learners designed spacecraft to gather data about Mars. As scientists, they chose a mission. As engineers, they figured out which instruments to send on the mission.	**Today**, learners generate questions about Mars before they explore how wind and water can make landforms on a planet's surface using models.	**Next time**, they will examine images of Mars to identify landforms which may have been formed by liquid water. These images are the first set of data they will use to choose a landing site.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

[place holder qr code and link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster (on paper or a shared digital document)
    - index cards
    - markers
    - scissors
    - tape
- 6 copies of *Landforms Handout*
- 3 copies of *Wind Station Directions*
- 3 copies of *Water Station Directions*
- 3 bags, trash, (clear, if possible)
- 3 baking (cookie) sheets with raised rims
- 3 pieces cardboard wrapped with aluminum foil with small notch cut (alluvial fan barrier)
- 24 cleaning wipes (1 per learner, to clean safety glasses between users)
- 3 cups
- 6 drop cloths, tarps, or large trash bags (if working inside)
- 12 pairs safety glasses
- 3 jugs, bottles, or watering cans, for refilling
- 24 face masks (1 per learner)
- 3 pans or boxes, 9″ × 13″ (approx. 23 cm × 33 cm), such as dish pans, aluminum baking pans, or copy-paper box lids lined with plastic

Teaching Tip

To let learners shape larger landforms, consider providing longer pans or stream tables.

- 3 cups gravel or pebbles
- 3–6 rocks, large, dry
- 10.5 cups of completely dry sand

- 24 straws (1 per learner)
- water
- 6 page protectors (optional)
- gloves, plastic (optional)

For each group of four

- items marked *1 per learner* in Landforms Stations, above

Teaching Tip
Quantities listed are for three setups per landform station (6 stations total). Three setups per landform station accommodate 24 learners total (6 groups of 4). If you have fewer learners, reduce the materials quantities and create fewer stations as appropriate.

Activity 1 Materials Preparation (60 min)

Ahead of Time

1. Print one copy of the *Landforms Handout* in color, if possible, for each group of 2–4 learners, in addition to the six copies needed for the stations.

2. Print three copies of *Wind Station Directions* and three copies of *Water Station Directions* for learners to reference when they are at the stations.

In Your Space

3. If you did not do so before the Ready, S.E.T., Go activity, prepare an *Our Ideas* poster by following the *Prep & Setup Guide*.

4. See *Station Assembly Instructions* on pp. X–Y for instructions on using the materials to set up the stations. Ensure all learners can access the stations.

Pages for Activity 1

- *Image of Mars Handout*

[RS_EDG_SCI_1_Image_of_Mars_Handout_Thumbnail]

- *Image of Mars in Context of the Solar System Handout*

[RS_EDG_SCI_1_Image_of_Mars_In_Context_of_ Solar_System_Handout_Thumbnail]

- *Landforms Handout*

[RS_EDG_SCI_1_Landforms_Handout_Thumbnail]

- *Wind Station Directions*, p. X

[RS_EDG_SCI_1_Wind_Station_Directions_Thumbnail]

- *Water Station Directions*, p. X

[RS_EDG_SCI_1_Water_Station_Directions_Thumbnail]

Teaching Tips

Laminate or place the *Landforms Handouts* in page protectors or large plastic zip-top bags to keep them from getting wet at the Water Station. Learners can write on them with dry erase markers, and they can be reused. You can reuse the *Landforms Handouts* from the stations instead of making new ones for each group.

To reduce mess, work outdoors. Use a hose for the Water Stations and create the dunes for the Wind Stations directly on concrete.

Play sand or aquarium sand work well. If you are able to find only wet sand, be sure to build in time to spread it out and let it dry.

Do one station at a time on different days to reuse the sand, saving the Water Stations for the end to keep the sand dry.

For safety at the Wind Station, have learners wear safety glasses and masks to prevent the sand from blowing into their eyes and noses.

Level Up!

Craters are visible in the images of Mars. If you have time, add a Crater Station by following online directions such as those on the Activity Resources page. Craters are fun and interesting to model but usually are not directly related to finding water on Mars. (30 min.)

Activity Guide

Get Ready and Team Up (15 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** (*As scientists, we chose a kind of mission to send to Mars. As engineers, we designed a spacecraft in order to complete that mission.)*

2. Say: **NASA has sent several global survey and landing site survey missions to Mars. As scientists, our ultimate goal is to analyze the data collected by these missions and answer the question "What is the best landing site for a Mars rover?"** Write the question on the *Our Ideas* poster. (Leave room at the end of this question to add the words "to look for past liquid water.") **Answering this question will help make sure the rover is able to land safely and carry out its mission, so people back on Earth are able to learn more about Mars.**

3. Distribute one *Image of Mars and its Context in the Solar System Handout* and one *Image of Mars Handout* per group. Ask: **What smaller questions will we need to answer in order to answer this question?** Allow learners to think of questions in pairs, then share them with the whole group. Record their questions on the *Our Ideas* poster in related categories. Possible sets of questions include the following:

    - **Evidence of Life:** What evidence of life is there? Where is there water? What are the most interesting areas? What is the weather/atmosphere like?

- **Safe Landing Sites:** What is the landscape like? Where is the safest place to land a rover? Can rovers go everywhere or are they limited? How much space does a rover need?
- **Minerals:** What is the land made of? Which minerals are evidence of liquid water?

Teaching Tip

Each activity in this pathway has a suggested Guiding Question. As much as possible, replace these questions with similar ones from the list of questions learners have thought of. Using learners' questions will increase their engagement. There will likely be questions you do not answer in the pathway. When you can, mention these questions and have learners think about ways to answer them in the future.

Learners may not ask these questions directly, but they may ask related questions. For example, "Was there life on Mars?" can be answered by looking for evidence of past water. Landforms and minerals can provide evidence of past water.

4. Say: **Those are all great questions. Today, we will start to answer questions about evidence of life.** If it hasn't come up, say, **Liquid water is needed for life. If liquid water was once present somewhere, it could have once supported some form of life. Scientists say the place could once have been habitable.**

5. Say: **The search for liquid water is the driving force behind several NASA missions. Turn to a neighbor and discuss: What do you already know about the importance of water?** After a few minutes, invite learners to share with the group. *(Answers may be similar or vary by culture. Encourage learners to draw from their experiences, stories from Elders, families, teachers, etc. Accept all answers as equally valid.)*

Support Thinking

Asking learners to discuss a few broad questions at the beginning of an activity surfaces helpful prior knowledge and acknowledges and values their experiences. This provides a more inclusive entry-point to developing new understandings.

Level Up!

The Engineering Pathway, *Worlds Apart: Engineering Remote Sensing Devices,* challenges learners to design many different remote sensing technologies to gather data from a distance.

6. Say: **As scientists, your task is to examine data collected by remote sensing technologies that engineers designed. You will use these data to choose the best site to send a rover to**

look for past liquid water. Then, you will compare your choice to NASA's. At the top of the *Our Ideas* poster, write "to look for past liquid water" after "What is the best landing site for a Mars rover" so that it says: "What is the best landing site for a Mars rover to search for past liquid water?"

7. Organize learners into groups of four.

Support Learner Differences Group learners with different abilities and strengths in a way they can all contribute. Check out *Intentional Grouping Strategies*, p. X.

Explore Landforms (20 min)

1. Say: **The shapes on the surface of a planet are called *landforms*. Turn to your neighbor and discuss: What are some landforms that you know about here in our community?** Have learners record landforms on the *Our Ideas* poster.

Support Thinking

As learners engage with important but perhaps unfamiliar concepts and vocabulary terms, provide visuals and examples to amplify their understanding. Invite them to share translations, both orally and in writing, of the terms in their preferred language. If time permits, ask learners to think of additional examples of the concept/term that they know from previous experiences. Allow time for them to add ideas to their Notebook Glossaries.

Support Learner Differences

Introduce the idea of a "sense of place": the meanings of and attachment to a place built from a person or community's experience. Have students discuss places that are meaningful to them and their connections to those places.

2. Say: **Scientists often examine landforms to learn about the past history and climate of a location. Today, we will think about how landforms might hold evidence of past liquid water.** Write the Guiding Question and share it or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **What are landforms and how are they formed?**

3. Say: **Before scientists study landforms and other things on Mars, they make sure they understand how they work on Earth. Here on Earth, what are some ways you can tell that water used to be somewhere, even though it is gone now?** *(Dried mud with cracks, ripples in sand, dry riverbeds, rounded rocks, lines, such as on the side of a teacup or bathtub, and patterns, such as the collapse of land at the edge of a riverbed.)* Prompt learners to think about communities they belong to and what they see after a rainstorm or windstorm.

Support Thinking
Make connections to local phenomena with which learners are familiar, such as nearby hills, washes, and sources of water. If possible, share satellite images of the community and point out some of these locations.

4. Say: **Today, we will explore these ideas with models of Earth. In small groups, you will come to two stations. You will use sand, water, and air, representing wind, to model different landforms. You will rotate through both the stations, spending about 10 minutes at each.**

   a. Demonstrate as you say: **Each station has a *Landforms Handout* that shows types of landforms. Try to make the landforms by acting out the natural processes involved, like water and wind.**

   b. At the Wind Station, demonstrate how to have a partner hold the bag open as learners use a straw to blow across the sand to form dunes. Encourage learners to explore placing large rocks as obstacles. As needed, give learners time to feel the materials at the station.

   c. At the Water Station, demonstrate how to create a river valley by tilting a container of sand and slowly pouring water into it at the higher end in one location. Encourage learners to explore tilting at different angles and to try to make different landforms. Caution learners to tilt the container gently, so they do not spill the sand. Demonstrate how to pour water slowly in one spot on one side of a barrier and explore what happens to the sand. As needed, give learners time to feel the materials at the station.

Teaching Tip
Precisely replicating the landforms is not the goal. In fact, they likely cannot be the same because the scale is so different. The goal is for learners to explore and get a sense of what water and wind can do before looking at the images of Mars. Encourage learners to think about and discuss their experience with wind- and water-related landforms in nature.

Support Learner Differences
Consider running this activity as a whole group, guiding learners to create specific landforms, or as a demonstration rather than allowing groups to freely explore.

Support Thinking
Remind learners that they are creating models of how landforms naturally develop. So, learners should not sculpt the landforms with their hands. The idea is to allow the “natural” processes (wind, water) to create the landforms. Emphasize safety as you demonstrate.

5. While groups are working, ask: **Do you have any of these landforms in communities you belong to? What do you notice about the shapes of different landforms when you observe them from above?** *(Snakes, rope, fans, etc..)*

6. As a group gains experience with each landform, have learners in that group look at the examples and read the landform’s name and description from the *Landforms Handout*.

Reflect (10 min)

1. Gather the whole group. Ask: **Which landforms were you able to make? Which were you not able to make? Why?** *(Sand dunes were difficult to make because of the scale of the images, etc..).* **What similarities or differences did you notice between landforms on Earth and Mars? What do these observations tell you?** *(Landforms are similar on Earth and Mars, suggesting that Mars has things like wind and water on it.)* **Why might scientists be interested in these landforms?** *(Landforms formed by water on Earth may provide evidence of past liquid water on Mars.)*

Support Thinking
When introducing questions that require learners to extend their thinking and formulate new ideas, invite them to share ideas with a partner or small group before sharing with the whole group.

Consider adding these landforms and images to a chart/poster to reinforce new vocabulary.

2. Revisit the Guiding Question: **What are landforms and how are they formed?** *(Wind, water, and volcanic activity on other planets create the same landforms that they do on Earth. Alluvial fans, deltas, and river valleys form in water. Sand dunes are formed by wind, and lava flows are formed by volcanic activity.)* Have learners record their ideas on the *Our Ideas* poster. As needed, remind learners of the term *habitable* and *landforms*.

3. Ask: **What are the different ways that land is shaped by water near our community?** *(Hills, mesas, mountains, plateaus; canyons, valleys, lakes, ponds, deltas etc..)* Encourage learners to name or describe their experiences with specific landmarks. Consider returning to learners' ideas at the start of the next activity.

4. Say: **Good job working as scientists today! Now you are prepared for next time, when you will examine images of Mars showing landforms at potential landing sites. The process you are following is like the process NASA uses to choose landing sites.**

After the Activity

1. Clean up:

    - Keep the *Our Ideas* poster for Activity 2.
    - Throw away the straws, face masks, cleaning wipes, and gloves (if used). Allow the sand to dry. Store all Wind and Water Station materials for reuse.

2. Plan ahead for Science Activity 2. See Activity 2 Materials Preparation on p. X.

3. Take time to reflect on the following educator prompts: **How did you support learners' needs in acquiring the vocabulary used in this activity? How could you use similar strategies during future activities?**

Remote Sensing Unit Resources QR code leads to resources available for this unit. QR code https://planets-stem.org/topic/remote-sensing

Wind Station Assembly Instructions

Use these materials to set up the Wind Station. Three setups are needed for a group of 24 learners. The Materials list at the start of this Activity has additional details about the materials.

Materials for each setup:

- pp. X–Y, Wind, from *Landforms Handout*
- pp. X–Y, Other, from *Landforms Handout*
- 1 page protector
- 8 straws
- 1 cookie sheet
- ½ cup dry sand
- 1 drop cloth
- 1–2 rocks
- 1 trash bag
- 4 safety glasses
- 8 cleaning wipes
- 8 face masks
- *Wind Station Directions*

1. If learners are working inside, lay out the drop cloth underneath the work area to make sand cleanup easier.
2. Place the cookie sheet inside the trash bag.
3. Pour the sand onto the cookie sheet.
4. Fold the bag closed until learners are ready to use it. You can use a rock to hold it closed.
5. Put the *Landforms Handout* in the page protector and place it next to the bag. Put the *Wind Station Directions* nearby.
6. Place the straws, safety glasses, cleaning wipes, and face masks next to the bag.

In the Wind Station setup, the pan is placed inside a trash bag for protection. Plastic sheet protectors keep the handouts from getting sandy.

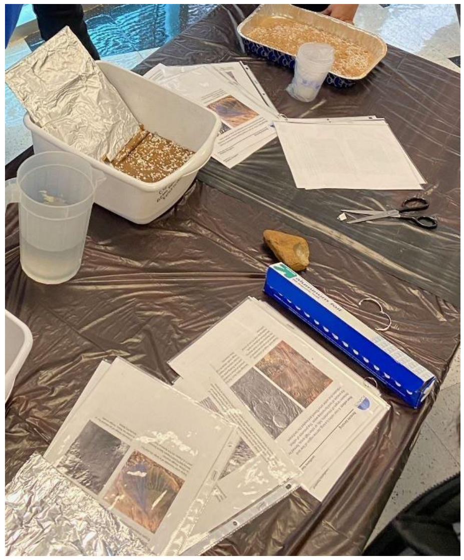
Water Station Assembly Instructions

Use these materials to set up the Water Station. Three setups are needed for a group of 24 learners. The Materials list at the start of this Activity has additional details.

Materials for each setup:

- pp. X–Y, Water, from *Landforms Handout*
- pp. X–Y, Other, from *Landforms Handout*
- 1 page protector
- pan or box
- 1 cup
- Mixture of 3 cups dry sand and 1 cup pebbles or gravel
- 1 drop cloth
- 1 jug
- 1 alluvial fan barrier
- water
- *Water Station Directions*

1. If learners are working inside, lay out the drop cloth underneath the work area to make water cleanup easier.
2. Place the pan or box on the drop cloth.
3. Fill the pan or box with the sand and pebble mixture.
4. Create the alluvial fan barrier. Cut a piece of cardboard the width of the pan. Cover it in aluminum foil. Add a 1″ notch at the bottom to allow water to stream through the hole.
5. Put the *Landforms Handout* in the page protector and place it next to the pan of sand. Put the *Water Station Directions* nearby.
6. Set the cup and alluvial fan barrier next to the pan of sand.
7. Fill the jug with water and place it near the pan of sand.

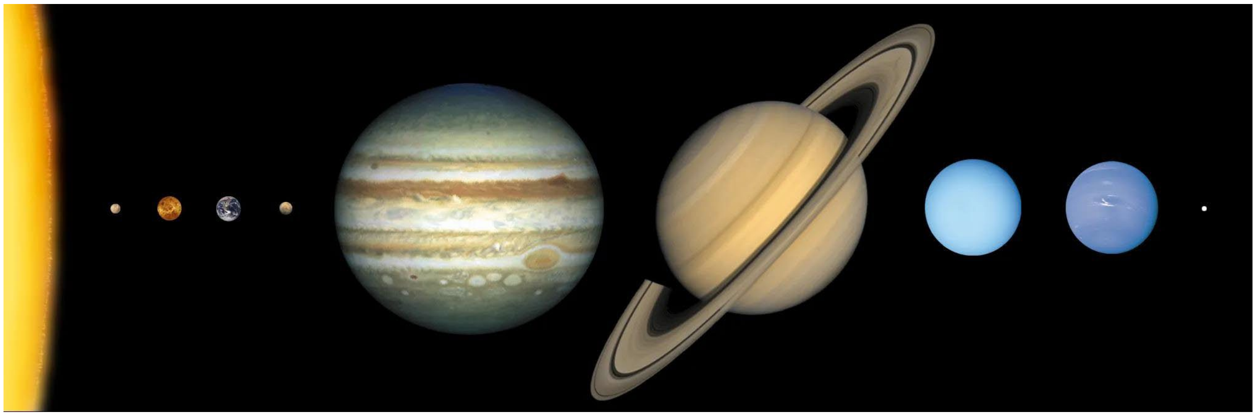


2. In the Water Station setup, the table is covered with plastic to protect against spills. Two pans hold the gravel and sand mixture; an alluvial fan barrier is placed in one of them. Plastic cups are provided for pouring and a pitcher of water for refilling. Plastic sheet protectors keep the Landforms Handouts from getting wet.

3. A close-up view of the alluvial fan barrier. The one-inch notch allows water to flow through and create a fan-like shape in the sand. This barrier simulates what happens to water when it flows from a mountainous area where it can't spread out, into a low-lying flat area where it can spread out.

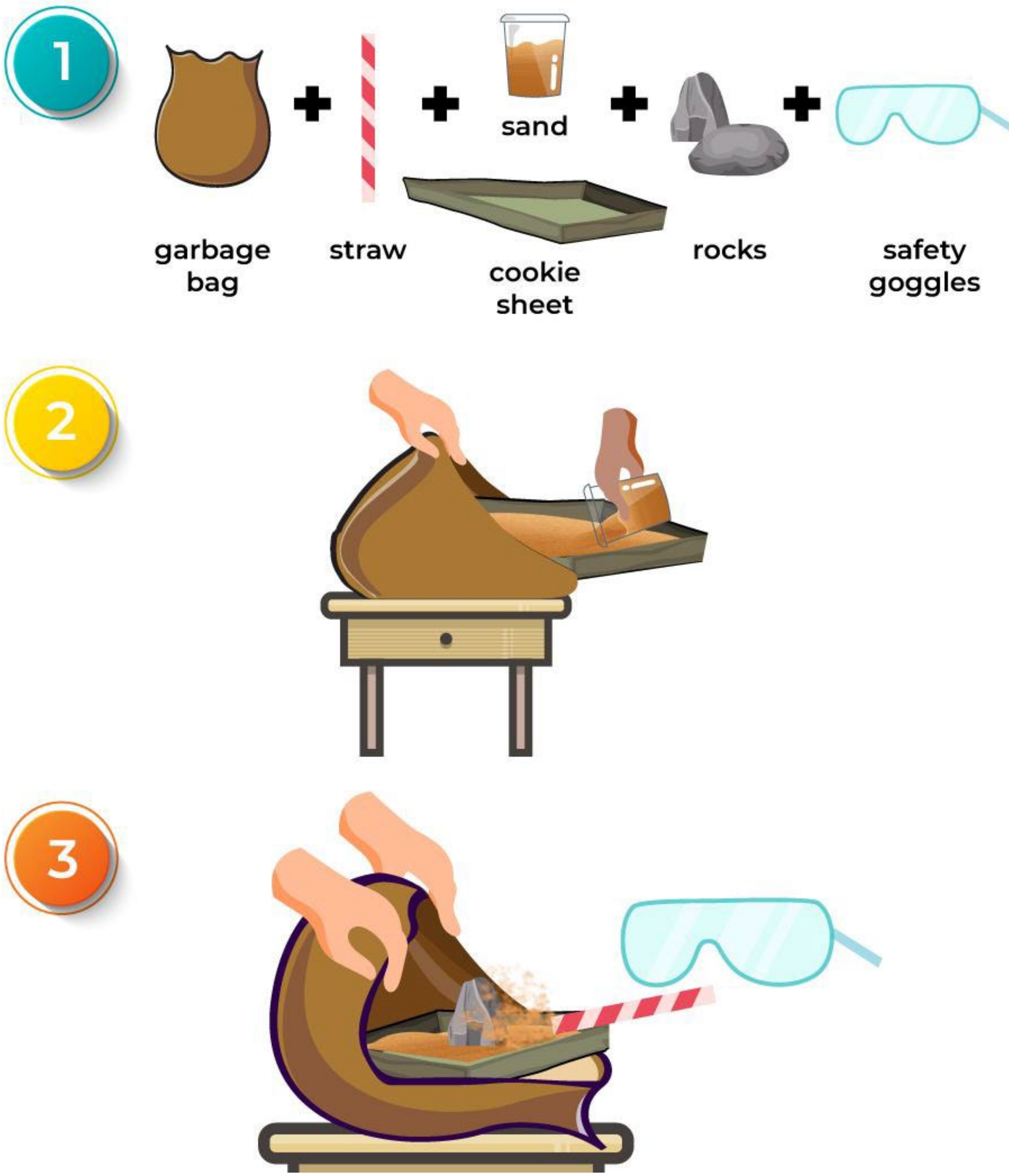
Image of Mars

Image of Mars in the Context of the Solar System



Science Activity 1

Wind Station Directions



1. Have one person hold the bag open. Have the others use straws to blow gently across the sand to form dunes, ripples, or other "landforms".

2. You can try placing large rocks as obstacles.

3. Examine the dunes you make.

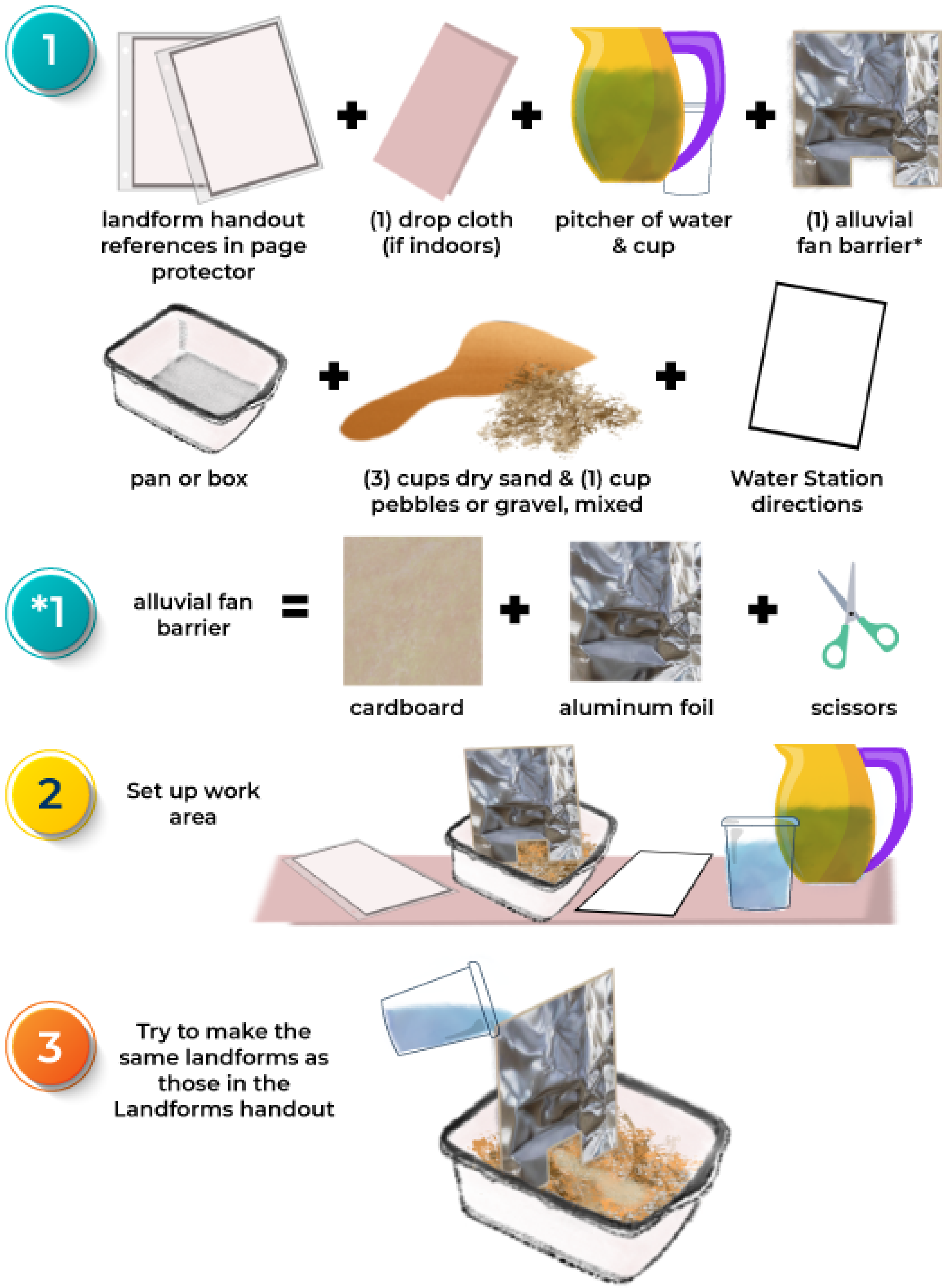
    a. How are your dunes like the dunes on the *Landforms Handout*? How are they different?

    b. Where have you encountered landforms like these before?

    c. What do you notice about the shapes of different landforms when you observe them from above?

    d. What are the different ways that land is shaped by wind near communities you belong to?

Water Station Directions



1. Try to make landforms from the *Landforms Handout* by pouring water into the sand. Pour from the cup and refill from the pitcher as needed.
2. To make a river valley, try tilting the container and slowly pouring water into it at the higher end in one location.
3. Explore tilting at different angles and to try to make different landforms. Make sure to tilt the container gently, so you do not spill the sand.
4. Try pouring water slowly in one spot on one side of a barrier and explore what happens to the sand.
5. Examine the landforms you make.
    a. How are your landforms like the ones in the *Landforms Handout*? How are they different?
    b. What do you notice about the shapes of different landforms when you observe them from above?
    c. What are the different ways that landforms are shaped by water near communities you belong to?

Science Activity 1

Landforms Handout

Science Activity 2: Red Planet Places: Exploring Landforms on Mars

Educator Preview

Activity Snapshot

Learners examine images of landforms on Mars to find evidence of past water.

Timing		Prep Snapshot*	21st Century Skills Connection
Get Ready and Team Up	10 min	Prep Time 60 min	● Critical Thinking
Search for Evidence of Water	20 min	Print resources.	**Science Practices**
Reflect	15 min		● Analyzing & Interpreting Data
Total	**45 min**	**See Materials & Preparation for full info*	

Guiding Question
How can landforms help us choose a landing site on Mars?

Learners Will Do

Recognize landforms on Mars that provide evidence of past water.

Learners Will Know

Mars has landforms similar to those on Earth.

Connecting Across Activities

Activity 1: Introducing Landforms	Activity 2: Exploring Landforms on Mars	Activity 3: Introducing Topography
Last time, learners generated questions about Mars and explored how wind and water can make landforms on a planet's surface using models.	**Today**, learners act as scientists to examine images of landforms on Mars. These images are the first set of data they will use to choose a landing site.	**Next time**, they will deepen their understanding of landforms by considering topography.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code
[link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster

For each group of four

- 1 copy of *Landforms Handout* from Science Activity 1
- 1 copy of *Science Activity 2 Landforms on Mars Data Packet* (in color and in page protectors, if possible)
- 1 *Landing Site Oval* (on transparency, if possible)
- 1 dry-erase marker, fine point (optional, if using page protectors)
- 1 piece felt or soft paper to erase marker (optional, if using page protectors)

For each learner

- Science Notebook

Activity 2 Materials Preparation (60 min)

Ahead of Time

1. Review the "In-Use Example" in the *Prep & Setup Guide* to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.

2. Print one *Science Activity 2 Landforms on Mars Data Packet* in color, if possible, for each group of 2–4 learners. Note: Data Packets are large files (XX) and should be downloaded and printed ahead of time.
3. Print one copy of *Landing Site Ovals* on transparency or regular paper. Cut along the dotted lines to separate the ovals so there is one oval for each group of 2–4 learners. Cut around the oval to make individual ovals.
4. Print the images in *Science Activity 2 Landforms on Mars Data Packet* in 3D and/or swell paper if you are using this option.

In Your Space

5. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally. Add a section divided into two columns. Title one column "Gale Crater" and the other "Jezero Crater."

Level Up!
If you are using the advanced version of this pathway with four possible landing sites, use the advanced version of the *Science Activity 2 Data Packet* and add columns titled "Nili Fossae" and "Iani Chaos" to the *Our Ideas* poster.

Pages for Activity 2

- *Landforms Handout*

[RS_EDG_SCI_1_Landforms_Handout_Thumbnail]

- *Science Activity 2 Landforms on Mars Data Packet*

[RS_EDG_SCI_2_Science_Activity_2_Data_Packet_Thumbnail]

- *Landforms We Notice*, Notebook p. X

[RS_EDG_SCI_2_Landforms_We_Notice_Thumbnail]

- *Landing Site Ovals*

[RS_EDG_SCI_2_Landing_Site_Ovals_Thumbnail]

Activity Guide

Get Ready and Team Up (10 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

6. Ask: **If you did the last activity, what did you do and why?** *(We generated questions about Mars including what the landscape was like and if there was life and water there. We explored models of Earth to understand how landforms form from water and wind. We compared images of landforms on Earth to images of landforms on Mars.)* Draw learners' attention to the list of landforms on the *Our Ideas* poster.

7. Say: **Our challenge is to choose the best landing site to search for past liquid water.**

8. Say: **Today we will focus on answering questions about the landscape of Mars.** Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can landforms help us choose a landing site on Mars?**

9. Organize learners into groups of four and distribute Science Notebooks.

Search for Evidence of Water on Mars (20 min)

1. Say: **Now that you have some experience with landforms, you are ready to explore real NASA Mars data to search for landforms that may have been created by liquid water to see if Mars was once able to support life, or habitable.** Give one *Landforms Handout* to each small group.

Support Learner Differences

Have learners discuss their knowledge of local landforms and the ways that those landforms are connected to water.

2. Provide each small group with a *Science Activity 2 Landforms on Mars Data Packet.* Tell groups to write their group name on this packet, so they get the same packet back to refer to in future sessions. Say: **Scientists need images to study planets from a distance. Multiple NASA spacecraft are circling Mars, and they have cameras on them that take pictures of the surface. These pictures are one type of data sent back from the spacecraft that you can now explore.**

3. Say: **You will study the data from two potential landing sites (Gale Crater and Jezero Crater). Then, you will choose a place on each possible site to land a rover.** Demonstrate as you point out the following:

    a. The *Map of Mars* and the explanation of each site on pp. 2–3 in the *Science Activity 2 Landforms on Mars Data Packet.*
    b. Each site has multiple images. Each set of images provides different information about each site.
    c. Viking images are really zoomed out and have less detail.
    d. Context Camera (CTX) and High-Resolution Imaging Science Experiment (HiRISE) images are of the same sites but are more zoomed in and provide more detail than the Viking images.

4. As they investigate, have learners fill out *Landforms We Notice*, p. X in the Science Notebook.

Level Up!

Although this activity lists two possible landing sites, if you have time, the activity is more interesting and enriching with four choices. See the website for the additional landing site data and directions.

Support Thinking

Share information about the current Mars orbiters to support understanding of the process of data collection.

5. Hold up a *Landing Site Oval* as you say: **Landing on Mars is difficult! Engineers can design a rover to land in an area 10 miles by 5 miles (16 km by 8 km), but they can't pinpoint the landing location any better than that. This oval represents the landing area. To stay safe on Mars, rovers drive slowly over short distances, so a scientifically interesting landing site should contain evidence of past liquid water within the oval or very nearby.**

Support Thinking

Help learners think about how big the oval is by talking about local landmarks that are 5 miles (8 kilometers) and 10 miles (16 kilometers) away. It's a large area!

If learners ask why landing on Mars is difficult, you can tell them that Mars has an atmosphere that is thick enough to burn up a spacecraft without a heat shield, but not thick enough for a parachute to slow the spacecraft down enough to land safely. Mars is also far away from Earth, so the spacecraft must go through the whole landing process automatically: it takes too long for radio signals to travel between Earth and Mars for a human to land the spacecraft with a joystick.

6. Demonstrate as you say: **With your group, you will choose and trace scientifically interesting landing site ovals within the Gale Crater and Jezero Crater Context Camera (CTX) images** (point out the Context Camera (CTX) images in the packet)**. Do not trace ovals on the High Resolution Imaging Science Experiment (HiRISE) or Viking images because the size of those images isn't the same as the oval size** (point out where it says “Do not place an oval on this image”) these images on the packet)**.**

Teaching Tip

Suggest roles that group members can fill, such as organizing the data, searching for landforms, and tracing the oval.

Support Learner Differences

Allow learners to first use their preferred language to think about and describe their work before using and applying the vocabulary and definitions from this activity in English.

7. Pass out a *Landing Site Oval* and a dry erase marker, if you are using page protectors, to each small group. Provide time for groups to choose and trace landing site ovals within the Gale Crater and Jezero Crater Context Camera (CTX) images.

Level Up!
Tell learners that the Viking landers had landing ellipses more than 100 km long, but improvements in science and engineering have shrunk the uncertainty of Mars landings down to within just a few kilometers. Future missions may be able to land with pinpoint accuracy.

Have learners find out more about the mission types NASA uses to gather information about a planetary body surface. For Mars, these include the remote sensing instruments Mars Reconnaissance Orbiter (MRO); High Resolution Imaging Science Experiment (HiRISE), Compact Reconnaissance Imaging Spectrometer for Mars (CRISM), landers and rovers (Insight, Spirit, Opportunity, Curiosity), and sample return (Perseverance). On the Moon, the Apollo and Artemis missions included sample return. (10 min.)

Reflect (15 min)

1. Invite groups to share the landforms at each site and note which provide evidence of past water. Record their ideas on the *Our Ideas* poster.

Note
Use the following key for reference, but do not share it with learners.

- Gale Crater contains a <u>river valley, alluvial fan, layered rocks*</u>, sand dunes, and craters.
- Jezero Crater contains a <u>delta, river valley</u>, lava flow, crater rim, and craters.

<u>Alluvial fans, deltas, and river valleys are evidence of water.</u>
*Layered rocks sometimes form in water, other times not.

2. Revisit the Guiding Question on the *Our Ideas* poster. Ask: **How can landforms help us choose a landing site on Mars?** *(Alluvial fans, deltas, and river valleys all provide evidence of water. If these are present at a site, liquid water may have once been present at that site, so it might be a good landing site to find evidence of habitability.)* Ask: **What questions do you still/now have?**

(What other types of data—besides visual data—are available? What are the size and scale of the landforms?, etc..)

3. Ask: **Which of the water-related landforms have you seen in your everyday life? Are there other water-related landforms that you can think of that were not discussed here? Why not?** *(Mud cracks and rounded stones are good indicators of water, but they are too small to be seen from orbit, etc..)* Consider returning to learners' ideas at the start of the next activity.

Support Thinking
Encourage learners to keep an eye out for these same water-related landforms the next time they look at a natural landscape from above, such as in online maps or from an airplane.

4. Say: **Good job working as scientists today! The visual data that was collected by the cameras engineers designed is essential, but it provides only some information. You will need other types of remotely sensed data to choose a landing site — you cannot rely on just one sense. Now you are prepared for next time, when you will explore a different type of remotely sensed data that can give you more details about the surface of Mars. The process you are following is like the process NASA uses to choose landing sites.**

After the Activity

1. Clean up:
    - Keep the *Our Ideas* poster for Activity 3.
    - Collect the *Science Notebooks*, *Science Activity 2 Landforms on Mars Data Packets*, and *Landing Site Ovals*.
2. Plan ahead for Science Activity 3. See Activity 3 Materials Preparation on p. X.
3. Take time to reflect on the following educator prompts: **How did you get learners engaged in data analysis? How could you use similar strategies during future activities?**

Remote Sensing Unit Resources
QR code leads to resources available for this unit.
QR code
https://planets-stem.org/topic/remote-sensing

Landing Site Ovals

Science Activity 2

Landforms on Mars Data Packet

Science Activity 3: Shape Up: Introducing Topography

Educator Preview

Activity Snapshot

Learners build three-dimensional models of topographic maps and then turn them into two-dimensional maps.

Timing	**Prep Time 30 min**	**21st Century Skills Connection**
Get Ready and Team Up 10 min Build Topographic Models 25 min Reflect 10 min **Total 45 min Prep Snapshot***	Print resources for the Activity. *See Materials & Preparation for full info	● Critical Thinking **Science Practices** ● Analyzing & Interpreting Data ● Planning Investigations

Guiding Question

How can maps help us understand a planet's landscape?

Learners Will Do

Interpret topographic maps to identify flat areas and landforms.

Learners Will Know

A topographic map represents the three-dimensional shape of land in an area in two dimensions.

Connecting Across Activities

Activity 2: Landforms on Mars	Activity 3: Introducing Topography	Activity 4: Exploring Topography on Mars
Last time, learners acted as scientists to examine images of landforms on Mars. These images are the first set of data they will use to choose a landing site.	Today, they deepen their understanding of landforms by considering topography.	Next time, they will interpret Mars topographic maps. These maps are the second set of data they will use to choose a landing site.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code [link]

Materials and Preparation

Materials

For the whole group

- Our Ideas poster

For each group of four

- Topography Template
- 1 sheet of foam, craft
- scissors
- tape, masking
- glue sticks (optional)
- writing utensils (pencils or crayons), colored, in gradually darker shades of yellow, green, and blue if possible
- Resealable bag or paper clip (optional)
- Grand Canyon Topographic Map or local topographic map

- Grand Canyon Aerial Photo or local aerial photo

Support Learner Differences
Consider providing the cut foam pieces instead of having learners cut them using the Topography Template handout.

Activity 3 Materials Preparation (10 min)

Ahead of Time

1. Review the “In-Use Example” in the Prep & Setup Guide to help you think about what to add to the Our Ideas poster during the discussions in this activity.
2. Make copies of the Topography Template for each group of four.
3. Make a sample topography model using the directions on Topography Template, p. X.
4. Obtain or download topographic maps and aerial images of your local area if you are using this option. You will need Adobe Reader or comparable PDF viewing software to use the option below.
   a. To find a topographic map of your local area, follow this link to the USGS TopoView website. Search for your location in the search field in the upper right.
   b. Once you have found your location, narrow down the list of available maps by adjusting the Date slider in the upper right to only show recent years.
   c. Select a map from the list and click the “Show” icon to show it on the main map. If this looks like it covers the correct area, download a GeoPDF file of the map.
   d. There is a lot of information in the PDF, but if it’s too cluttered, you can turn some of it off. When you open the PDF in Adobe Acrobat, you should see a list of “layers” on the left. If you don’t see this, go to View > Show/Hide > Side Panels/Navigation Panes > Layers
   e. For the simplest possible topographic map, you can turn off all layers except for “Contour Features”. However, you may find it useful to keep some other layers turned on, such as “Transportation” (to see roads) or “Geographic Names” (to see landmarks).
   f. You may also choose to zoom in on the map to see details more clearly.
   g. To see a satellite view/aerial photo of the map area, turn on the Images layer in the PDF and turn off contours.
5. Print one Grand Canyon Topographic Map and Grand Canyon Aerial Photo (or local versions) per group of four learners.

In Your Space

6. Place the Our Ideas poster in a visible place in your learning setting or prepare to share it digitally.

Support Thinking
We suggest you start this activity by going outside and exploring the local terrain. Choose an area with some noticeable elevation changes, if possible. A topographic map of the Grand Canyon is provided in case you live in a very flat area; however, we highly recommend you download a topographic map from topoView and aerial images of an area that is familiar to learners. This is especially important if you are unable to go outside.

Pages for Activity 3

- Landing Site Ovals

[RS_EDG_SCI_2_Landing_Site_Ovals_Thumbnail]

- Topography Template

[RS_EDG_SCI_3_Topography_Template_Thumbnail]

- Grand Canyon Topographic Map

RS_EDG_SCI_3_Grand_Canyon_Topographic_Map_Thumbnail

- Grand Canyon Aerial Photo

RS_EDG_SCI_3_Grand_Canyon_Aerial_Photo_thumbnail

Activity Guide

Get Ready and Team Up (10 min)

Support Learner Differences
If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X). For more strategies to engage learners, refer to Designing Instruction to Reach Diverse Learners, pp. X–Y.

1. Ask: If you did the last activity, what did you do and why? (We examined images of Mars to identify water-based landforms. We chose which landing site would be most interesting to send a rover to.) Invite learners who were present to share findings from the Our Ideas poster and their notebooks.

2. Say: Our challenge is to choose the best landing site to search for past liquid water.

3. Say: Today we will focus on choosing a safe landing site. On the Our Ideas poster, focus on the questions about how safe and easy it is to land a rover on Mars. If there are no questions in this category, ask: What else might we need to know about the landforms or the rover? (The size and height of the landforms, the materials they are made from; space the rover needs, etc..) Invite learners to add additional questions.

Teaching Tip

Learners may not ask these questions directly, but they may ask related questions. For example, "Where can a rover land?" can be answered by knowing the topography and limitations of the rover.

4. Share the Guiding Question or a similar question from the Our Ideas poster with learners aloud and in writing (using multiple languages as needed): How can maps help us choose a safe and interesting landing site on Mars? Say: You will get to explore real maps of Mars later, but first you will make models to understand how maps can show the height of the land. Then it will be easier for you to understand the Mars maps.

5. Organize learners into groups of four.

Build Topographic Models (25 min)

Support Thinking

If time and weather permit, go outside and travel with learners across areas of varying height and slope. Ask: What do you notice about the height of the land as we travel? (It is going up or down; it is steep, not steep, or flat; it is difficult or easy to travel on; or it is a landform such as a valley or hill, etc..) Where would be the best place to have a picnic or play a game of soccer? Why? When would it be good to know ahead of time if the land is steep or not? Why? (Before traveling across the land so we know how difficult it will be and if we need special equipment to help us, etc..)

If your environment allows, have learners spread out to areas of different heights. Have learners observe each other spatially and ask: How could we record these changes in height on a map? (Using color, texture, measurement numbers, or lines to represent different heights, etc..)

1. Hold up your sample topography model as you say: Today we will create a model of a hill using foam pieces to represent the different heights of the hill. As needed, allow learners to feel the sample model.

2. Hold up the Topography Template and demonstrate as you say: You will get a paper template to create your model. The largest shape on the template represents the lowest spot on the hill. It will be the bottom layer. Each of the other shapes are slightly smaller and represent a slightly higher part of the hill. First, you will decide how to color each shape so you have darkest (shape 1, blue) to lightest (shape 7, yellow). Then, you will cut out the shapes.

Support Learner Differences

Encourage learners to use patterns or textures instead of colors to indicate the different layers if they find that more useful or accessible.

Teaching Tip

Groups can cut the paper template in half or thirds, leaving one to four shapes on each section so multiple learners can color at once and then cut out the detailed shapes. This can be repeated with the cutting of foam.

3. Provide each group with one copy of the Topography Template Handout, scissors, and colored writing utensils. Allow them 5 minutes to color and cut out the shapes.

4. When groups are ready, demonstrate as you say: Next, trace the shapes onto one sheet of craft foam and cut out the craft foam pieces. You only get one piece of foam, so you have to plan carefully. Save these paper pieces - we will use them later. Then tape your craft-foam shapes together using tape loops on the back of each shape. Begin with the largest shape and attach the next smallest shape to it, and then the next smallest, so that each shape is fully within the boundary of the one below it.

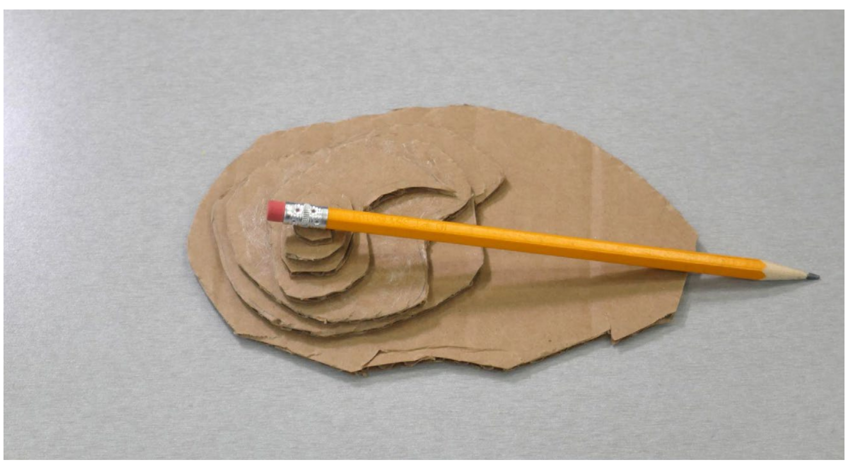
Teaching Tip

Provide each group with a bag or a paper clip to keep their cut paper template pieces together.
Using loops of tape between layers and not pressing layers down helps to accentuate the vertical dimension of the topographic models.

5. Provide one piece of craft foam, a roll tape and a glue stick (optional) per group and provide 5 minutes to create the models.

Support Learner Differences
As needed, provide groups with a tub or other container to hold their materials.

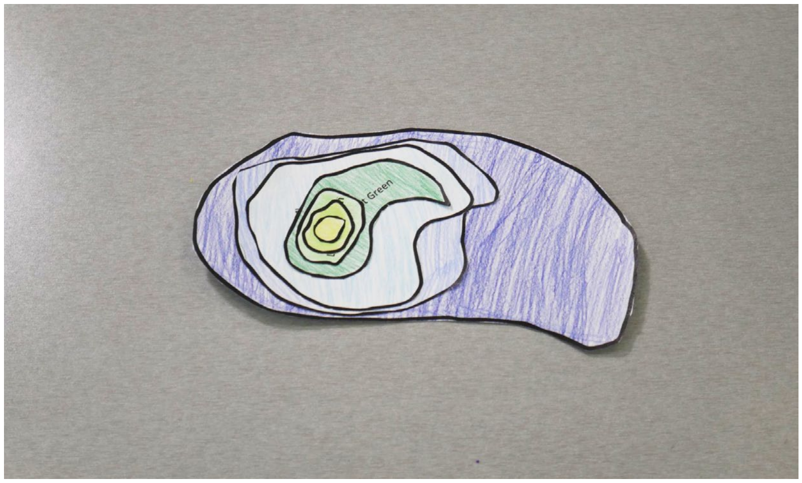
6. Say: Now you have a three-dimensional model of the shape of a hill. If we combine our models, we can make a three-dimensional model of the land. If time, invite learners to combine their models, leaving room in between to represent flat areas. As needed, give learners time to feel the combined model. Say: The shape of the land in an area is called that area's topography. Write the word topography on the Our Ideas poster.
7. Provide each group with a pencil. Use hand gestures to indicate changes as you say: Place the pencil on different parts of your craft-foam model. Using the information from the map, decide whether your oval/pencil would be flat or tilted if it was really in this location. (It would be tilted if it is sitting across lines and level/flat if it is not sitting across any lines.) Give them a few minutes to test their models. As they work, ask: If you want your oval/pencil to be stable and not tilt, where should you place it? Why? (You should place the oval/pencil on a single layer because it doesn't tilt there. If it is on multiple layers, it tilts.)



The best landing site will tilt the oval or pencil the least.

Support Thinking
The pencil is a way to measure the average slope across the area that it spans. Encourage learners to notice where the lines on the 3D model appear closer together. Ensure learners understand that lines that are closer together indicate steeper slopes.

8. Say: Because it's not easy to carry around three-dimensional models of places, we rely on flat, two-dimensional maps. Demonstrate as you say: Make a map from the paper pieces you saved. Tape or glue the layers of the paper templates in the same way as the foam pieces, then trace the outline of each layer so you can see the lines. Provide 5 minutes for learners to construct their maps.



9. While learners are working, help them understand their maps. Ask: Because these layers are all flat, how can you tell which layer stands for the highest area and which stands for the lowest? (The lightest color layer is the highest area, and the darkest color is the lowest.) What does each line represent? (Each line represents land at the same height.) What does it mean when the lines are close together? When they are far apart? (Where there are a lot of lines close together, the slope is very steep. When the lines are far apart, it is not as steep.) Are there areas around here that have topography similar to what is represented by this map? (Local steep areas, such as hillsides and cliffs, could be represented by areas of the map where the lines are close together. Local flat areas, such as fields and plains, could be represented by areas on the map where the lines are far apart.)

10. After learners have made their maps, say: The lines on your map trace places that are all the same height. If you walked one of these lines on the ground, you would never go up- or downhill. The different lines on your maps show different heights. Because the maps show topography, these maps are called topographic maps. You just created topographic maps. Write the term topographic map on the Our Ideas poster.

Support Thinking

To support understanding of the word topographic, tell learners that it comes from the roots topo, meaning "place," and graph, meaning "to write or draw." Have learners think of other words they know that come from similar roots, such as utopia (a good or nonexistent place), dystopia (a bad place), graph (a drawing of data), graphite (a soft mineral that leaves a gray streak, used to make pencil “lead”), and bolígrafo (Spanish for pen).

Allow learners to share stories about any previous experiences with topographic maps, such as when hiking or using depth finders for fishing. You can also prompt learners to consider the topography of indoor spaces, such as the height and arrangement of different items in a room.

11. Say: Now place the pencil on different parts of your paper model. Using the information from the map decide whether your oval/pencil will be flat or tilted in different locations. Give them a few minutes to test their models. As they work, ask: If you want your oval/pencil to be stable and not tilt, where should you place it? Why? (You should place the oval/pencil on a single layer because it doesn’t tilt there. If it is on multiple layers, it tilts.)

[RS_EDG_SCI_3_Topographic_Map_with_Pencil]

The best landing site will tilt the oval or pencil the least.

12. Provide each group with a Grand Canyon topographic map or the local topographic map. Provide 5 minutes for them to compare their topographic models to the topographic map. Ask questions such as: Where is the steepest area? (Where the lines are closest together). Where would you want to play soccer and why? (The flattest area.)

Reflect (10 min)

1. Revisit the Guiding Question on the Our Ideas poster. Ask: How can maps help us understand a planet's landscape? (They show the shape of land in an area. We can see how steep an area is by looking at the lines. If the lines are close together, the landscape is steep.) Remind learners of the terms topography and topographic map.
2. Ask: How might topographic maps help us choose a landing site? (They show the shape of landforms. Scientists can think about how much water might have been involved in the formation of the landforms. They also help choose a safe place to land.)
3. Ask learners: When might someone use a topographic map? (Prior to construction, farming, hiking, etc..)
4. Ask: What questions do you still/now have? (What other types of data—besides visual and topographic data—are available? What are the landforms made of?, etc.)

5. Good job working as scientists today! Now you are prepared for next time, when you will explore topographic maps of each of the potential landing sites. Remember, the process you are following is like the process NASA uses to choose landing sites.

After the Activity

1. Clean up:
   - Keep the Our Ideas poster for Activity 4.
   - Collect the topographic maps. Save them for reference in future activities or display at the Share-Out.
2. Plan ahead for Science Activity 4. See Activity 4 Materials Preparation on p. X.
3. Take time to reflect on the following educator prompt: How did you help learners understand the concept of a topographic map? How could you use similar strategies during future activities?

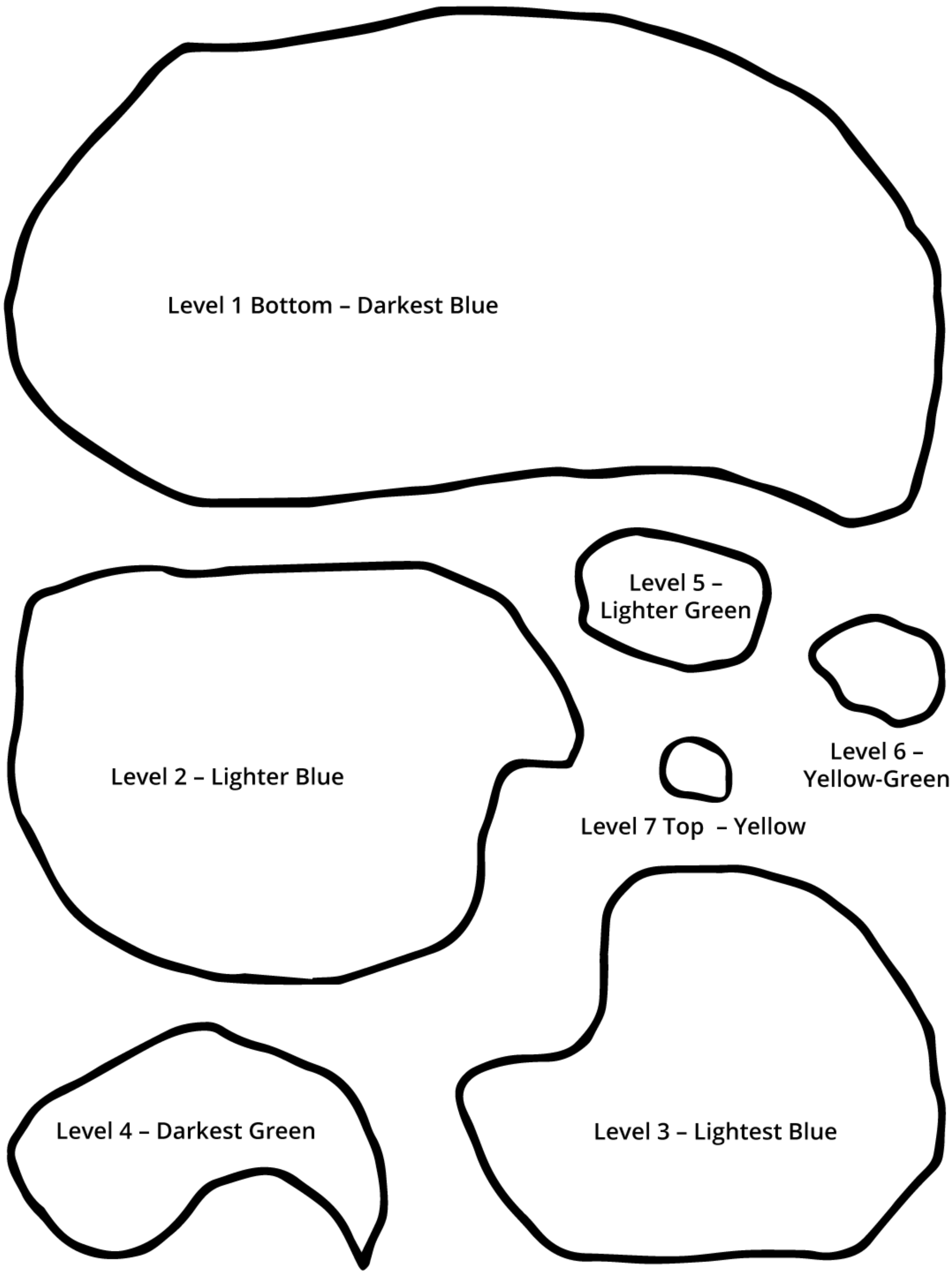
Remote Sensing Unit Resources

QR code leads to resources available for this unit.

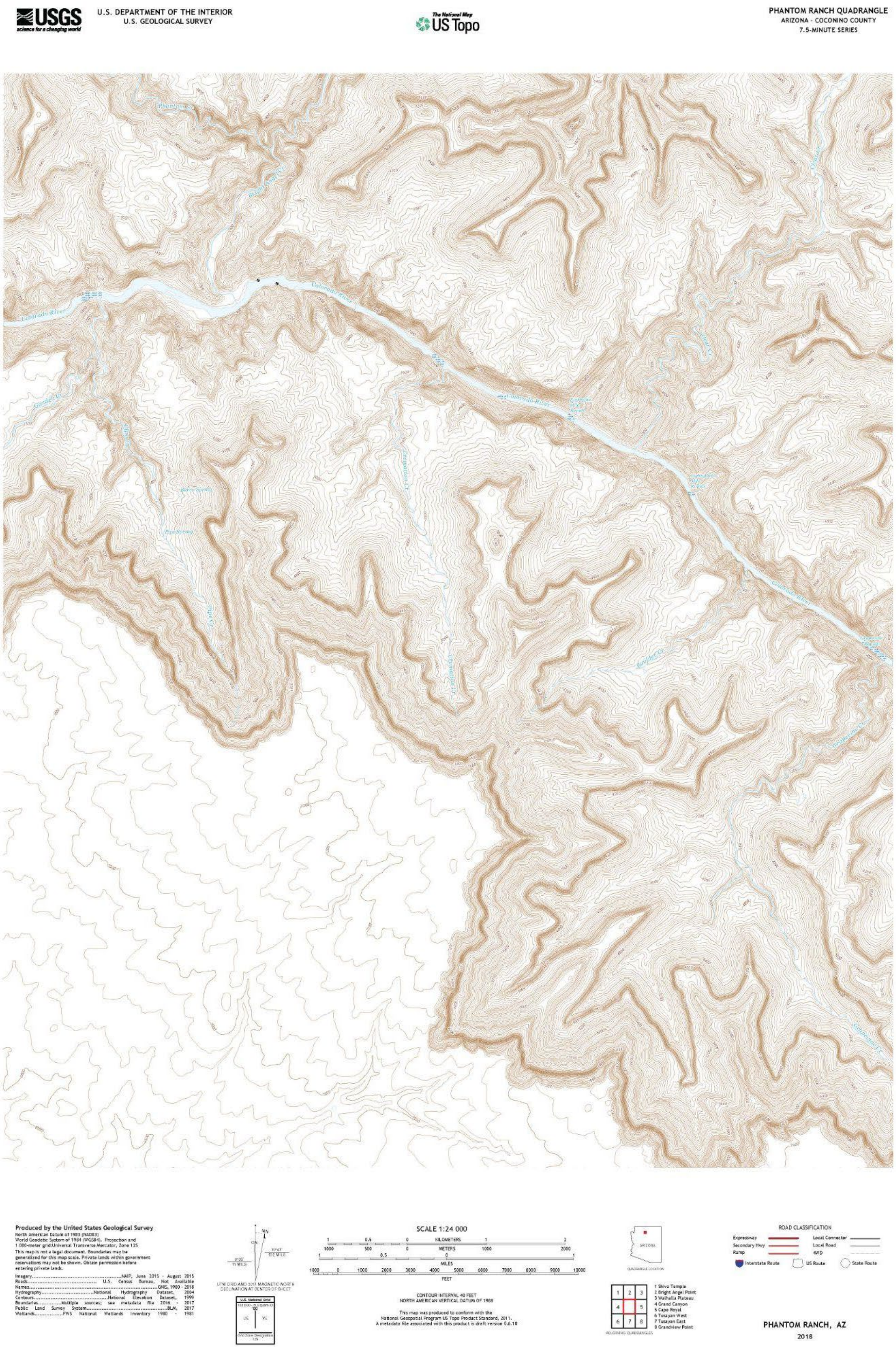
QR code https://planets-stem.org/remote-sensing

Topography Template

Cut out each layer and use it as a template to cut seven pieces of craft foam. Tape layers together to create a three-dimensional topographic model.


Level 1 Bottom – Darkest Blue
Level 5 –
Lighter Green
Level 2 – Lighter Blue
Level 6 –
Yellow-Green
Level 7 Top – Yellow
Level 4 – Darkest Green
Level 3 – Lightest Blue

Grand Canyon Topographic Map


U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
US Topo
PHANTOM RANCH QUADRANGLE
ARIZONA - COCONINO COUNTY
7.5-MINUTE SERIES
Produced by the United States Geological Survey
SCALE 1:24 000
CONTOUR INTERVAL 40 FEET
NORTH AMERICAN VERTICAL DATUM OF 1988
ROAD CLASSIFICATION
PHANTOM RANCH, AZ
2018

Grand Canyon Aerial Photo

Science Activity 4: Cliffs and Craters: Exploring Topography on Mars

Educator Preview

Activity Snapshot

Learners interpret topographic maps of Mars to identify safe and interesting landing sites.

Timing	Prep Snapshot*	21st Century Skills Connection
Get Ready and Team Up 10 min Analyze Landing Sites 25 min Reflect 10 min **Total 45 min** **Level Up Activities** 5–45 min each	Prep Time 30 min Print resources for the Activity. **See Materials & Preparation for full info*	● Critical Thinking **Science Practices** ● Analyzing & Interpreting Data ● Planning Investigations

Guiding Question

How can topographic maps help us choose a safe and interesting landing site on Mars?

Learners Will Do

Interpret topographic maps of Mars to identify flat areas and landforms.

Learners Will Know

A topographic map represents the shape of land in an area.

Connecting Across Activities

Activity 3: Introducing Topography	Activity 4: Exploring Topography on Mars	Activity 5: Introducing Spectroscopy
Last time, learners deepened their understanding of landforms by considering topography.	**Today**, learners interpret topographic maps of Mars to locate interesting landforms and to determine the safest place for a rover to land. These maps are the second set of data they will use to choose a landing site.	**Next time**, they will learn how to interpret spectra of light reflected from various objects, which will later help them identify minerals from a distance.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code
[link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster
- Play Doh or clay (optional)

For each group of four

- *Science Activity 2 Landforms on Mars Data Packet*
- *Science Activity 4 Mars Landing Site Topography Data Packet* (in page protectors, if possible)
- 1 *Landing Site Oval* from *Science Activity 2 Topography Data Packet*
- 1 dry-erase marker, fine point (optional, if using page protectors)

For each learner

- Science Notebook

Activity 4 Materials Preparation (10 min)

Ahead of Time

1. Review the "In-Use Example" in the *Prep & Setup Guide* to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.
2. Make copies of *Science Activity 4 Mars Landing Site Topography Data Packet* for each group of four. Note: Data Packets are large files and should be downloaded and printed ahead of time. Consider laminating the pages of *Science Activity 4 Mars Landing Site Topography Data Packet* or placing them into plastic page protectors to prevent them from getting damaged.
3. Print the images in *Science Activity 4 Mars Landing Site Topography Data Packet* in 3D and/or swell paper if you are using this option.
4. Create a clay model of each of the landing sites in *Science Activity 4 Mars Landing Site Topography Data Packet* to provide a tactile version of the data (optional). The models can be estimations based on the color changes; they do not need to follow the lines exactly.

In Your Space

5. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally. Add a section divided into two columns. Title one column “Gale Crater” and the other “Jezero Crater.”

Level Up! If you are using the advanced version of this pathway with four possible landing sites, use the advanced version of the *Science Activity 4 Data Packet* and add columns titled “Nili Fossae” and “Iani Chaos” to the *Our Ideas* poster.

Pages for Activity 4

- *Science Activity 2 Landforms on Mars Data Packet*

[RS_EDG_SCI_2_Science_Activity_2_Data_Packet_Thumbnail]

- *Science Activity 4 Mars Landing Site Topography Data Packet*

[RS_EDG_SCI_4_Science_Activity_4_Data_Packet_Thumbnail]

- *Topography We Notice*

[RS_EDG_SCI_4_Topography_We_Notice_Thumbnail]

- *Landing Site Ovals*

[RS_EDG_SCI_2_Landing_Site_Ovals_Thumbnail]

Activity Guide

Get Ready and Team Up (10 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** (*We built 3D models of topography and turned them into 2D maps. We learned how to interpret topographic maps*). Indicate the information about topography on the *Our Ideas* poster.

2. Say: **Our challenge is to choose the best landing site to search for past liquid water.**

3. Say: **Today, we'll continue to focus on choosing a safe landing site.** Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can topographic maps help us choose a safe and interesting landing site on Mars?**

4. Organize learners into groups of four and distribute Science Notebooks.

Analyze Mars Landing Sites (25 min)

5. Say: **Now that you understand how to read a topographic map, you are ready to explore topographic maps of Mars. To help scientists study the topography of Mars, engineers developed an instrument that gathers information about the size and height of landforms by bouncing a laser off them and measuring how long it takes the light to come back. By measuring the height of millions of different points on the surface using this laser,**

scientists know the topography of the entire surface of Mars.The technology is called *L*i*ght* *D*etection *a*nd *R*anging, or LiDAR. Record the term *LiDAR* on the *Our Ideas* poster.

Support Thinking
To help learners understand LiDAR, show the videos *Using Light to Measure Distance (LiDAR Theory)* and *Using Light to Map Surfaces (LiDAR Uses)*.

Level Up!
The Engineering Pathway, *Worlds Apart: Engineering Remote Sensing Devices,* goes into detail on how LiDAR works and challenges learners to engineer a model LiDAR device to capture the topography of a surface.

6. Provide a *Science Activity 2 Landforms On Mars Data Packet* and a *Science Activity 4 Mars Landing Site Topography Data Packet* to each group. Demonstrate as you say: **Examine the topography data packet and compare it to Landforms on Mars**. After a few minutes, ask questions to ensure learners notice the following:

    a. These topographic maps show the same area of interest as the Context Camera images for each of the landing sites they explored earlier.

    b. The colors match the color scale on the topographic maps they made in Session 3 (if they followed the suggested key).

Level Up!
Although this Activity lists two possible landing sites, if you have time, the activity is more interesting and enriching with four choices. See the website for the additional site data and directions.

7. Say: **Turn to *Jezero Crater: Topography*, pp. 38–39 in the *Science Activity 4 Mars Landing Site Topography Data Packet.* What do you think the color scale, or the difference in color and shading, means?** *(The colors represent height. Yellow represents high areas and blue represents low areas. [If printed in grayscale, brighter represents high areas and darker represents low areas.] The color scale shows the direction of the slope.)* **What do you think the lines mean?** *(As on the topographic maps earlier, each line represents a particular height.)*

8. Say: **Your task is to determine the safest and most interesting areas to land a rover. Examine the data to understand the topography of each location. Remember, your goal is**

to find evidence of past liquid water, to see if Mars was once habitable, so you will need to use your data about landforms from the *Our Ideas* poster as well.

9. As groups investigate, ensure they are interpreting the data correctly. Indicate different parts of the crater. Ask: **How steep is this area?** *(Where lines are close together and color varies quickly, the slope is steep, such as on a mountain. Where lines are far apart and color varies slowly, the slope is shallower, such as on a field.)* **What makes a good landing site, and which areas of the map are good landing sites?** *(A safe landing site should be in a flat area. Interesting landing sites include landforms that may have formed in water.)*

Level Up!
Tell learners that scientists often like to explore areas with steep slopes or rugged topography, where layers of rock might be exposed. Have them think about why these areas are interesting. (5 min.)

10. As they investigate, have learners fill out *Topography We Notice*, p. X in the Science Notebook.

11. Have groups share their observations of the topography of each site with the whole group and record them on the *Our Ideas* poster.

12. Pass out a Landing Site Oval and a dry erase marker, if you are using page protectors, to each small group. Say: **A safe landing site should be as flat as possible, while a scientifically interesting landing site should be on or near landforms that indicate past water. At each of the possible landing sites in the *Data Packet*, trace one oval showing where you think it might be safe and scientifically interesting to land.**

Reflect (10 min)

13. Ask: **Did your choice of landing site change when you got topographic maps? How or why?** *(We rated flat areas that are safe to land more highly than before, etc..)*

14. Revisit the Guiding Question on the *Our Ideas* poster**.** Ask: **How did topographic maps help us choose a safe and interesting landing site on Mars?** *(They helped us locate a safe, flat landing site near interesting landforms.)* Remind learners of the term *LiDAR*.

15. Ask: **When might it be important to find a flat location on Earth?** (*Pitching a tent, playing soccer, constructing a building, etc..*) Consider returning to learners' ideas at the start of the next activity.

Level Up!

Invite a family or community member to come in as a special guest and share their knowledge about hazard-related topics. (45 min)

16. Say: **Good job working as scientists today! Next time, you will explore a different type of remotely sensed data that relies on light. These data will help you answer questions about what Mars is made of. The process you are following is similar to the process NASA uses to choose landing sites.**

After the Activity

17. Clean up:

    - Keep the *Our Ideas* poster for Activity 5.
    - Collect the *Science Notebooks*, *Science Activity 2 Mars Landforms Data Packets*, *Science Activity 4 Mars Landing Site Topography Data Packets*, and *Landing Site Ovals*.

18. Plan ahead for Science Activity 5. See Activity 5 Materials Preparation on p. X.

19. Take time to reflect on the following educator prompt: **How did you help learners apply what they learned about topographic maps in the previous activity?**

Remote Sensing Unit Resources
QR code leads to resources available for this unit.
QR code
https://planets-stem.org/topic/remote-sensing

Science Activity 4

[Mars Landing Site Topography Data Packet]

Science Activity 5: Beyond the Rainbow: Introducing Spectroscopy

Educator Preview

Activity Snapshot

Learners interpret the spectra of reflected light from various objects.

Timing	Prep Snapshot*	21st Century Skills Connection
Get Ready and Team Up 10 min Introduce Spectroscopy 25 min Reflect 10 min **Total 45 min** **Level Up Activities** 5–30 min each	Prep Time 50 min At least two days ahead, create tactile spectra graphs and allow them to dry. Determine how learners will access audio files. **See Materials & Preparation for full info*	● Critical Thinking **Science Practice** ● Analyzing & Interpreting Data

Guiding Question

How can measuring reflected light help us identify different materials?

Learners Will Do

Interpret spectra to identify different materials.

Learners Will Know

Spectroscopy measures how much light of different colors (both visible and invisible) is coming from a material.

Connecting Across Activities

Activity 4: Topography on Mars	Activity 5: Introducing Spectroscopy	Activity 6: Using Spectroscopy to Understand Mars
Last time, learners interpreted topographic maps of Mars to locate interesting landforms and to determine the safest place for a rover to land. These maps are the second set of data they will use to choose a landing site.	**Today**, learners learn how to interpret spectra of light from various objects, which will later help them identify minerals from a distance.	**Next time**, they will interpret spectra to identify minerals at each of the different landing sites. These graphs are the third set of data they will use to choose a landing site.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code [link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster
- Assorted rocks and minerals, small, such as gravel mixture
- Audio file for Olivine
- Audio player and speaker
- School glue or puff paint (optional)
- Sand or glitter (optional)
- Computer with internet access (optional)

For each group of four–assembled tactile models:

- 1 copy of tactile model of *Red Paint*
- 1 copy of tactile model of *Green Paint*
- 1 copy of tactile model of *Olivine* from *Mineral Fingerprints Handout* (6 total tactile models) (optional)
- 1 copy of tactile model of *Electromagnetic Spectrum*, p. X in the Science Notebook (6 total tactile models) (optional)

For each learner

- Science Notebook

Activity 5 Materials Preparation (60 min, at least two days ahead of time)

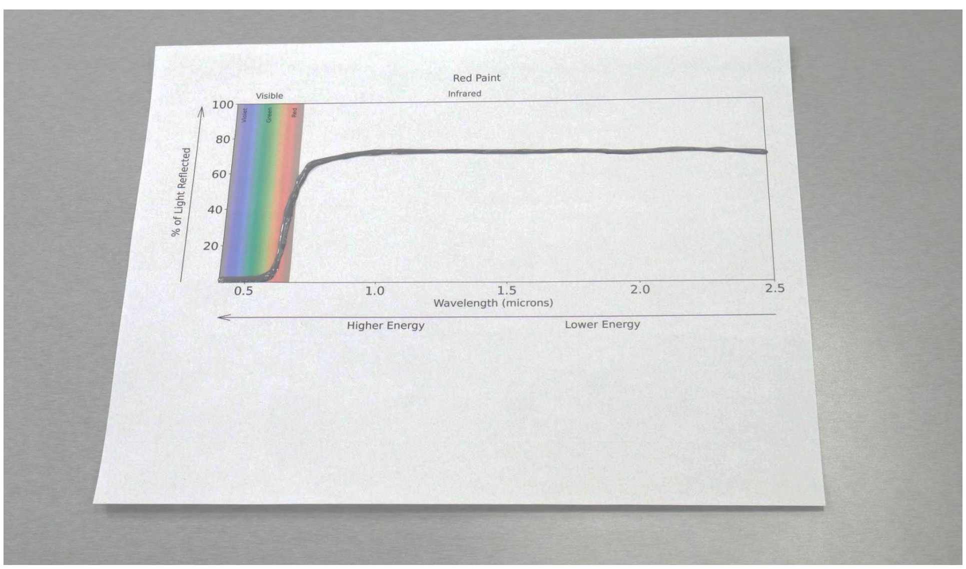
Ahead of Time

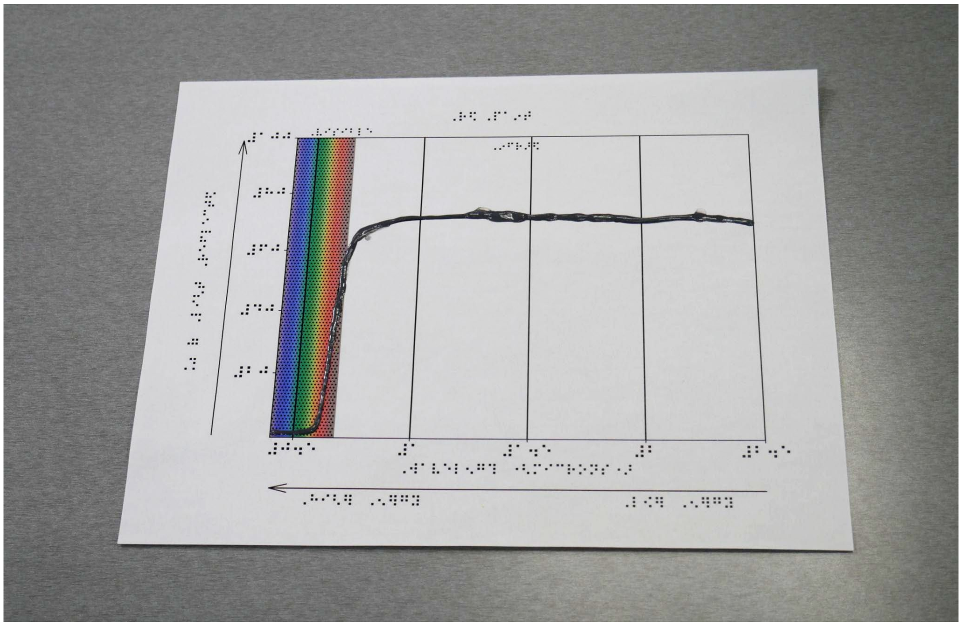
1. Review the “In-Use Example” in the *Prep & Setup Guide* to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.

2. Determine how you will share the audio files on the day of the activity with the whole group. You have the option to download the audio files or access audio files online.

Support Learner Differences
Although it is listed as optional, all learners will benefit from interacting with a tactile version of the spectra, and it will make for a more enriching experience. Learners trace the reflectance lines with their fingers as they listen to the audio files, making them active participants versus passive listeners. This will strengthen their connection to understanding the changes in the light that comes from the materials.

3. Prepare a tactile model by adding a line of glue or puff paint to the data line, to each of the axes, and on either side of the visible spectrum of *Red Paint, Green Paint* from Science Notebook p. X, and *Olivine Spectrum* from the *Mineral Fingerprints Handout*, and *Electromagnetic Spectrum*, p. X in the Science Notebook. Ensure you have a space to let the graphs dry. Consider sprinkling the glue with a bit of fine sand or glitter to add additional texture. This will give you enough materials for one group of four. Repeat as necessary so you have enough for half the learners in your program to access the tactile graphs at once. Alternatively, print these on swell paper.





Teaching Tip

To reduce the amount of color printing, you (or learners) can color in the visible light portion on the spectra.

If you are planning to make the tactile graphs, consider also preparing the tactile graphs for Activity 6 at the same time. See Activity 6 Materials Preparation, p. X.

If you are not planning to make tactile graphs, or if you are printing on swell paper, you do not need the two-day waiting period and can prepare closer to the start of this Activity.

In Your Space

4. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.

Pages for Activity 5

- Red Paint

[RS_EDG_SCI_5_Red_Paint_Thumbnail]

- Green Paint

[RS_EDG_SCI_5_Green_Paint_Thumbnail]

- *Electromagnetic Spectrum*, p. X

[RS_EDG_SCI_5_Electromagnetic_Spectrum_Thumbnail]

- *What Color Is Olivine?*, p. X

[RS_EDG_SCI_5_What_Color_Is_Olivine_Thumbnail]

Activity Guide

Get Ready and Team Up (10 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** (*We interpreted topographic data to find interesting landforms and to determine the safety of each landing site*). Draw learners' attention to their findings about landforms and topography on the *Our Ideas* poster.
2. Say: **Our challenge is to choose the best landing site to search for past liquid water.**
3. Say: **Today we'll focus on what Mars is made of to determine whether water was once there.** Refer to the questions on the *Our Ideas* poster about what the planet is made of, what rocks and minerals are present, and the presence of past water needed for life. If learners do not mention water, ask them what types of things NASA is interested in learning about Mars and why. It is important they focus on water for the rest of the activity. Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can measuring reflected light help us identify different materials?**

Teaching Tip

Learners may not ask questions about minerals directly, but they may ask related questions. For example, "Was there life on Mars?" can be answered by looking for minerals that form in water. Reinforce the connection between evidence for past water on Mars and the possibility of past life.

4. Organize learners into groups of four and distribute Science Notebooks.

Introduce Spectroscopy (25 min)

1. Give each group some rocks and minerals to examine for several minutes. Write the word *minerals* on the *Our Ideas* poster. Say: **There are not any plants on Mars, but there are a lot of rocks and minerals. Where have you heard the word *mineral*?** *(Precious minerals, minerals in our diet, etc.)* **What do you already know about minerals?** *(Minerals occur naturally and form crystals including quartz, salt, diamond.)* Have learners discuss in groups and add their answers to the *Our Ideas* poster.

2. Say: **Each kind of mineral forms in a certain way. Some minerals form only in water, so knowing which minerals are at each landing site can help us understand whether that site once had water.** Ask: **How might we figure out what kinds of rocks and minerals these are?** *(Weighing them, shining light on them, showing them to someone, etc..)*

Teaching Tip
Learners may know the terms *hardness*, *crystal structure*, *luster*, and *streak*, but it is not important to introduce these terms. Focus on the ways someone can collect evidence if they physically have a mineral.

3. Say: **Because we cannot touch the surface of Mars, we cannot use most of the ways scientists identify minerals on Earth. We must rely on cameras and other technologies on spacecraft orbiting Mars and on rovers on the surface. One useful way to learn about the world remotely is through color. That's why humans and many animals have color vision. Let's explore this idea a bit, before we come back to identifying minerals.**

4. Invite learners to review the colors marked "visible spectrum" on *Electromagnetic Spectrum*, p. 17 in their Science Notebooks. Say: **This diagram describes all types of light, visible and invisible, in a range of colors, or a spectrum.** Write the word *spectrum* on the *Our Ideas* poster. Say: **Notice that the part marked "visible spectrum" is only a small portion of the diagram. Most light cannot be seen by human eyes.** Ask: **What does this visible spectrum remind you of?** *(It looks like a rainbow).* **What do you know about rainbows?** *(They come out after rainstorms and when light passes through prisms.)*

5. Say: **When humans see a rainbow we are actually seeing all the visible colors of light.** Ask: **Besides rainbows, what other kinds of light listed here are familiar to you? What kinds are unfamiliar?** *(Ultraviolet light might be familiar because of sunscreens and blacklights; infrared light can be felt as warmth from heat lamps, etc.)*

6. Invite learners to notice the area marked “energy” on *Electromagnetic Spectrum,* p. X. Say: **Light’s color is a measure of its energy. In the visible spectrum, violet light has the most energy and red light has the lowest energy.** Point out ultraviolet, x-rays, gamma rays to the left of violet and infrared, microwaves, and radio to the right of red as you say: **Light with more energy than violet and light with less energy than red is invisible to humans.**

Support Thinking

Tell learners that many planets and moons are exposed to gamma rays and other types of radiation, or light energy from the Sun, that would be hazardous to humans. But just as we can learn information from visible and infrared data, we can learn things from gamma ray and x-ray data. The Mars Odyssey GRS (Gamma Ray Spectrometer) instrument detects gamma rays and other types of radiation to learn about the chemistry of the surface of Mars. The Radiation Assessment Detector on the Curiosity rover on Mars monitors radiation from space and will let us know how much shielding from radiation future Mars astronauts will need to be protected.

7. Say: **To identify different materials, scientists worked with engineers to design a technology that measures the colors of light coming from those materials. Because this technology measures a range of colors, or a spectrum, it is called a *spectrometer*.** Write the word *spectrometer* on the *Our Ideas* poster.

8. Point to the source of light in the room as you say: **When all of the colors in the spectrum come from the same place at about the same brightness, such as from the sun or a light bulb, human brains interpret that as white light. But, when more of one color than the others bounces off or is reflected back from an object, humans perceive it differently. For example, when humans see a stop sign, a lot of red light is reflected back, so we perceive it as red.**

9. Say: **Scientists often display data collected by spectrometers in a graph that is also called a *spectrum*. If we have more than one spectrum, we say *spectra*. We are going to study some spectra now.**

Level Up!

If time permits, allow learners to explore electromagnetic radiation through experience with prisms or heat lamps and explore how wavelength and frequency change based on the amount of energy put into a system using Slinkys. (20 min.)

Learners may also view the NASA Science Activation Network's e Clips videos that talk about and use the electromagnetic spectrum. Based on your group, consider replacing or adding to the above explanation with the video *Using Light to Find Out What Things are Made of (Spectroscopy)*. (5 min.)

Support understanding of spectrometers by having learners build their own spectrometers or explore resources about spectrometers before introducing the term *spectrometer*.
See more at Activity 5 Resources. (30 min.)

This unit's Engineering Pathway Activities challenge learners to design technologies similar to spectrometers that will help scientists distinguish between different materials.

Support Thinking

To support understanding of the word spectrometer, display the word and explain that it comes from roots spec, meaning "to observe," and meter, meaning "measure." Have learners think of other words that come from similar roots, such as spectator (someone who observes), spectacle (something people observe), thermometer (a tool for measuring temperature), and pedometer (a tool for measuring steps).

To support understanding of spectrometers, you can show or describe the Mars Reconnaissance Orbiter (MRO) and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument using Activity 5 Resources.

Support Learner Differences

If appropriate, distribute tactile models of Electromagnetic Spectrum, Red Paint, Green Paint and Olivine Spectrum, pp. 17, 20, 21, and 23 in the Science Notebook.

10. Say: **Look at p. X, *Green Paint* in your Science Notebooks. The graphed line, or spectrum, shows how much light of each color bounces off, or is reflected from, paint. If the sun shines on green paint, the paint absorbs most colors but reflects green light. Where the line is high, that color of light is reflected.** Ask**: Where on the graph does the green paint reflect the most visible light?** *(The peak in the graph is in the green band of light, so the green paint reflects the most visible light in the green range).* **Human eyes perceive objects as being different colors based on how much of each color of visible light they reflect. What color**

will the paint be to human eyes? *(You can tell from the peak in the graph on the green band of light that it will appear green).*

11. Say: **Now look at the spectrum of *Red Paint,* p. X. Where on the graph does this paint reflect the most visible light?** *(In the red band).* **What color will human eyes see?** *(Red)***.**

12. Say: **The amount of reflected light can be represented by lines on a graph, but it can also be represented using sounds. I will play audio files of the spectra for the two colors of paint.** Use hand gestures and your voice to indicate changes as you say: **Before I play them you must know:**

    - **The pitch, or how high or low the sound is, matches how much light is reflected as you go from left to right on the graph.**
    - **Beeps represent the wavelengths on the bottom of the graph.**
    - **As the pitch goes down, less light is reflected. As the pitch goes up, more light is reflected.**

13. Say: **Compare the audio file of the Green Paint Spectrum to the audio file of the Red Paint Spectrum while exploring the graphs in your Science Notebooks. Trace the graphs with your fingers as you listen to the sounds.** Play the two files a few times. Ask: **What differences do you notice between the sound of the green paint spectrum and the sound of the red paint spectrum?** Encourage learners to use gestures and voice to illustrate their ideas. *(The red paint audio is higher in pitch and is fairly steady. The green paint audio is lower in pitch and fluctuates.)*

14. Say: **Planetary scientists use spectrometers to identify minerals on other planets. Look at the spectrum of a common volcanic mineral called *olivine* on pages 22–23 of your Science Notebooks.**

15. Say: **Now I will play the audio file of the spectrum of olivine, so you can compare it to the sounds of the paint color spectra. Listen to the audio while exploring the graphs.** Play the audio file of olivine.

16. Ask: **What do you notice about the spectrum of light reflected by olivine? Is olivine's spectrum more like the green paint or the red paint? What color will olivine be to human eyes?** *(In the colors visible to humans, olivine reflects more green than other colors. Its spectrum is more like the green paint's spectrum, so it will appear green to human eyes.)*

Note

To learn more about spectroscopy, see Educator Background, p. X.

Support Thinking

Contrast LiDAR and spectroscopy. Explain that while LiDAR measures the *time* it takes for light of one energy to bounce between the aircraft and the surface of a planet, spectrometers measure the *intensity* (or *brightness*) of the light the surface reflects at many different energies/colors.

Reflect (10 min)

1. Revisit the Guiding Question on the *Our Ideas* poster: **How can measuring reflected light help us identify different materials?** *(We can tell what color something is by how much light it reflects.)* Remind learners of the terms *minerals*, *spectrum*, and *spectrometer*. Ask: **What questions do you still/now have?** Allow time for learners to add questions.

2. Ask: **When might it be useful to know about light beyond the visible spectrum?** *(Studying ultraviolet light helps us to develop sunscreens, x-rays help us see broken bones, NASA shields astronauts from gamma rays, etc..)* Consider returning to learners' ideas at the start of the next activity.

3. Say: **Good job working as scientists today! Now you are prepared for next time, when you will use spectra to identify minerals at each of the potential landing sites. Remember, the process you are following is like the process NASA uses to choose landing sites.**

After the Activity

1. Clean up:

    - Keep the *Our Ideas* poster for Activity 6.
    - Collect the *Science Notebooks* and tactile spectra. Save the *Olivine* graphs for use in the next Activity.

2. Plan ahead for Science Activity 6. See Activity 6 Materials Preparation on p. X.

3. Take time to reflect on the following educator prompts: **How did you connect the topics in this activity, such as colors and types of light, to learners' prior knowledge and experiences? What strategies can you use again in the future?**

Remote Sensing Unit Resources QR code leads to resources available for this unit. QR code
https://planets-stem.org/topic/remote-sensing

Science Activity 6: Hidden Minerals: Using Spectroscopy to Understand Mars

Educator Preview

Activity Snapshot

Learners interpret spectra to identify water-based minerals at potential Mars landing sites.

Timing	Prep Snapshot*	21st Century Skills Connection
Get Ready and Team Up 10 min Analyze Mars Landing Sites 25 min Reflect 10 min **Total 45 min** **Level Up Activities** 20 min each	Prep Time 50 min At least two days ahead, create tactile spectra graphs and allow them to dry. Determine how learners will access audio files. **See Materials & Preparation for full info*	● Critical Thinking **Science Practice** ● Analyzing & Interpreting Data

Guiding Question
How can identifying minerals help us choose a landing site on Mars?

Learners Will Do

Interpret spectra to identify minerals on Mars that have formed in water.

Learners Will Know

There are many “colors” of light humans can’t see, but engineers build instruments to measure them.

Connecting Across Activities

Activity 5: Understanding Spectroscopy	Activity 6: Using Spectroscopy to Understand Mars	Activity 7: Choosing a Landing Site and Preparing for the Science Share-Out
Last time, learners learned how to interpret spectra of light reflected from various objects, which will later help them identify minerals from a distance.	**Today**, learners interpret spectra to identify the types of minerals at each of the different landing sites. These graphs are the third set of data they will use to choose a landing site.	**Next time**, they will use the various kinds of data they have collected–landform images, topographic maps, and spectra – to choose a landing site.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code
[link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster
- Audio files for Leaf and Mineral Fingerprints Data
- 6 audio player(s) with headphones (or learners' personal devices)
- Wipes to clean headphones after each use (if using)
- School glue or puff paint (optional)
- Sand or glitter (optional)
- Computer with internet access (optional)
- 3 copies of each image in *Science Activity 6 Data Packet*
- 3 additional copies of Spectra Pages in *Science Activity 6 Data Packet* (if planning to make Tactile Spectra Models)
- 6 copies of *Mineral Fingerprints Handout*
- 6 additional copies of *Mineral Fingerprints Handout* (if planning to make Tactile Spectra Models)
- 1 copy of *Mineral Station Signs* (3 signs per station)

For each group of four–assembled tactile models:

- 1 copy of tactile model of Comparing Green Things - Visible (6 total tactile models)
- 1 copy of tactile model of Comparing Green Things - Visible and Infrared (6 total tactile models)

Assembled tactile models:

- 3 copies of tactile models of *Gale Crater Data* (4 spectra), pp. 44–53 from *Science Activity 6 Data Packet* (12 total spectra models) (optional)
- 3 copies of tactile models of *Jezero Crater Data* (3 spectra), pp. 62–69 from *Science Activity 6 Data Packet* (9 total spectra models) (optional)
- 6 copies of tactile spectra models of *Mineral Fingerprints Handout* (6 spectra models per station; 36 total spectra models) (optional)

For each learner

- Science Notebook

Activity 6 Materials Preparation (60 min, at least two days ahead)

Teaching Tip

Stations will run concurrently, three stations for each landing site (Gale Crater and Jezero Crater). Each site will include visual graphs, audio files, and tactile graphs for each of the minerals in *Mineral Fingerprints Handout*. Ensure there are enough materials at each station for one group of four.

To reduce the amount of color printing, you (or learners) can color in the visible light spectra on the graphs.

If you are not planning to make tactile graphs, or if you are printing them on swell paper, you do not need the two-day waiting period and can prepare closer to the start of this Activity.

Ahead of Time

1. Review the "In-Use Example" in the *Prep & Setup Guide* to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.

1. See *Mineral Fingerprints Stations Assembly Instructions* on pp. X–Y for instructions on using the materials to set up the tactile and audio stations.

2. Determine how learners will access the audio files on the day of the activity. You have the option to download the audio files for each spectrum or provide the learners the QR codes or links to the files if you plan to have learners access audio files online.

3. Make copies of *Mineral Fingerprints Handout, Science Activity 6 Data Packet,* and the *Mineral Station Signs*. Note: Data Packets are large (## MB) files. Download and print these ahead of time.

4. Prepare a tactile model of each spectrum by adding a line of glue or puff paint to the data line, to each of the axes, and on either side of the visible spectrum, on each graph. Prepare 6 copies of each graph in *Mineral Fingerprints Handout* (6 graphs per station; note that *Olivine* graphs were created for the previous Activity). Prepare 3 copies of each graph in *Science Activity 6 Data Packet* (7 graphs). Ensure you have a space to let the graphs dry. Consider sprinkling the glue with a bit of fine sand or glitter to add additional texture. Alternatively, print these on swell paper.

5. Print, fill, and copy a Science Share-Out flier for each learner to send home at the end of the Activity in preparation for the Science Share-Out in Activity 8.

In Your Space

6. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally. Add a section divided into two columns. Title one column “Gale Crater” and the other “Jezero Crater.”

Level Up!

If you are using the advanced version of this pathway with four possible landing sites, use the advanced version of the *Science Activity 6 Data Packet* and audio files. Add columns titled “Nili Fossae” and “Iani Chaos” to the *Our Ideas* poster.

Support Learner Differences

Although it is listed as optional, all learners will benefit from interacting with a tactile version of the spectra, and it will make for a more enriching experience. Learners trace the reflectance lines with their fingers as they listen to the audio files, making them active participants versus passive listeners. This will strengthen their connection to understanding the changes in the light that comes from the materials.

You will need to create 21 tactile spectra, three copies each of pp. 44–61 in the *Science Activity 6 Data Packet*. You will also need to create tactile spectra of the six known minerals, pp. 2, 6, 10, 14, 18, and 22 in *Mineral Fingerprints Handout* (note that you created tactile graphs of olivine for the previous Activity). Ideally, you will provide one tactile copy of the entire *Mineral Fingerprints Handout* per station, but one or two tactile versions of this resource could be shared among stations. If appropriate, solicit help.

Pages for Activity 6

- *Science Activity 6 Data Packet*

[RS_EDG_SCI_6_Science_Activity_6_Data_Packet_Thumbnail]

- *Mineral Fingerprints Handout*

[RS_EDG_SCI_6_Mineral_Fingerprints_Handout_Thumbnail]

- *Minerals We Notice*, Science Notebook p. X

[RS_EDG_SCI_6_Minerals_We_Notice_Thumbnail]

- *Comparing Green Things - Visible*, Science Notebook p. X
- [RS_EDG_SCI_6_Comparing_Green_Things_Visible_Thumbnail]
- *Comparing Green Things - Visible and Infrared*, Science Notebook p. X
- [RS_EDG_SCI_6_Comparing_Green_Things_Visible_and_Infrared_Thumbnail]
- *Science Share-Out Flier*

[RS_EDG_SCI_6_Science_Share-Out_Flier_Thumbnail]

Activity Guide

Get Ready and Team Up (10 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** (*We learned that scientists learn about materials using the light reflected off them. We practiced interpreting spectra using our eyes and our ears*, *including the spectrum of a mineral called olivine.)* Refer to the terms related to spectra on the *Our Ideas* poster.
2. Say: **Our challenge is to choose the best landing site to search for past liquid water.**
3. Say: **Today we'll continue to focus on what Mars is made of to determine whether water was once there.** Refer to the questions on the *Our Ideas* poster about what the planet is made of and what rocks and minerals are present to indicate the presence of past water needed for life. If learners do not mention water, ask them what types of things NASA is interested in learning about Mars and why. It is important they focus on water for the rest of the activity. Share the Guiding Question or a similar question from the *Our Ideas* poster with learners aloud and in writing (using multiple languages as needed): **How can identifying minerals help us choose a landing site on Mars?**
4. Organize learners into groups of four and distribute Science Notebooks.

Support Learner Differences

If appropriate, distribute tactile models of Electromagnetic Spectrum, Comparing Green Things - Visible and Comparing Green Things - Visible and Infrared, pp. 17, 20, and 23 in the Science Notebook.

Analyze Mars Landing Sites (25 minutes)

1. Say: **Turn to *Electromagnetic Spectrum*, page X in your Science Notebooks.** Give them a few minutes to review, noticing the visible and invisible portions. Say**: The Electromagnetic Spectrum includes both visible and invisible light from the Sun.**

2. Say: **Turn to *Paint Colors*, page X in your Science Notebooks**. Give them a few minutes to review and reorient how to interpret the graphs.

Support Learner Differences
If appropriate, play the audio files for *Paint Colors, Olivine - visible, Green Leaf - visible*

3. Say: **Those spectra were two colors of the same material - paint. Spectrometers were engineered to help scientists identify different types of materials. Turn to *Comparing Green Things - Visible* page X in your Science Notebook**. Allow groups a few minutes to notice differences and similarities. Ask: **In the visible spectrum**, **how does the leaf spectrum compare to the olivine spectrum? What color will these appear to human eyes?** *(The visible spectra are very similar–they all reflect the most green light and will appear different shades of green to human eyes)* Say: **Sometimes materials have very similar spectra in the visible range so they look the same to humans. It might be very difficult for scientists to tell these two materials apart, just by looking at their spectra.**

Support Learner Differences
If appropriate, play the audio files for *Paint Colors, Olivine - visible and infrared, Green Leaf - visible and infrared*

4. Say: **Remember from the *Electromagnetic Spectrum* page X, there are colors of light humans can't see. Spectrometers measure infrared light. It is invisible, so it does not affect the colors humans see, but it is important for identifying materials. Turn to *Comparing Green Things - Visible and Infrared,* page X*.* Notice the reflection lines don't stop in the visible part of the spectrum. They keep going to the right of red.** Ask: **How does the olivine spectrum compare to the green leaf spectrum in infrared light?** *(They were very similar in visible light, but they have very different spectra in infrared light.)* **That's why scientists examine spectra that include more than just visible light when they are trying to identify materials.**

5. Say: **Spectrometers measure both visible and invisible light reflecting off objects to create spectra like these. Every material has a one-of-a-kind spectrum. That means the shape of spectra can be used like fingerprints to identify unknown materials. As scientists, we can interpret the shapes of different spectra and match them to the shapes of spectra from the laboratory to identify unknown materials.**

Level Up!

Some animals can see colors of light that humans can't, and vice versa. If learners are interested in how different animals see color differently, point them to the RadioLab episode "Rippin' the Rainbow a New One." (20 min.)

Although this activity lists two possible landing sites, if you have time, the activity is more interesting and enriching with four choices. See the website for the additional site data and directions.

6. Say: **Engineers designed a spectrometer that is onboard a spacecraft orbiting Mars. The spectrometer has measured the visible and infrared light reflecting off minerals at each landing site location. You are now ready to interpret these spectra to find out if there are any minerals that form in water at each of the possible landing sites.**

Support Thinking

Show the video *How We Use Spectroscopy to Learn About Other Planets* to help learners understand how spectroscopy is used to identify minerals on planets like Mars.

7. Explain the Site Data Stations:
   - Demonstrate as you say: **I have set up stations around the room. Each station represents a landing site, Gale Crater or Jezero Crater. Each landing site station includes audio files and spectra of different minerals.**
   - Show learners the *Mineral Fingerprints Handout* as you say: **This is a list of minerals and how they form. Some of these minerals form in water and some do not. When you get to a station, preview the *Mineral Fingerprint* pages. You will need to find the minerals that form in water, because these will provide evidence of habitability.** Demonstrate by finding the information on the first fingerprint page.
   - Demonstrate as you say: **Each site also includes a map showing the location of some unknown minerals at that landing site. Your task is to use the audio files and**

spectra to identify the unknown minerals at each site. **As you investigate, fill out *Minerals We Notice*, page X in your Science Notebook.**

Support Thinking

Remind learners to trace what the pitch of the sound is doing with their finger on the table while they listen to the audio.

8. Invite learners in groups of four to visit each Site Data Station and use spectroscopy data to identify the unknown minerals. As they work, remind them to look for minerals that form in water because they might indicate evidence of past liquid water (and therefore habitability).

Teaching Tip

You can have groups stay together or have members split up and go to different stations.

Suggest roles that group members can fill, such as referring to observations, moderating discussion, and recording the group's choices.

If learners are having trouble interpreting the spectra, you can emphasize that the important thing is that each material has a one-of-a-kind spectrum. Although it is better if learners understand what the graphs are showing, this activity still works as a simple matching exercise: to identify the mineral, find the spectrum with the same shape.

9. As learners explore, ask: **What do you gain by identifying minerals using audio as compared to the visual and tactile models?** *(It is easier to notice certain aspects of the data in one form rather than another.)*

10. When they have finished exploring, invite small groups to share their observations of the minerals at each site with the entire group. Record them on the *Our Ideas* poster. Ask: **Using the information you gathered about minerals, which sites do you think might have had water in the past?** *(Both sites have minerals that form in water.)* Say: **With your group, rank the sites based on the number of water-based minerals present at each site.**

Note

Refer to the following list of minerals at each site but do not share it with learners:

Gale Crater: Olivine, <u>Nontronite (forms in water)</u>, <u>Kieserite (forms in water)</u>, <u>Gypsum (forms in water)</u>

Jezero Crater: Olivine, Pyroxene, Kaolinite (forms in water)

Note

The patterned areas on the mineral maps in the *Science Activity 6 Data Packet* are idealized and simplified, but they are based on actual observations of these locations on Mars. The minerals listed really are at these locations!

Support Learner Differences

To make this Activity more challenging, have learners consider which minerals that form in water the rover could reasonably access from a safe landing oval, and which might be too far away or in places with dangerous topography.

Reflect (10 min)

1. Revisit the Guiding Question on the *Our Ideas* poster: Ask: **How can identifying minerals help us choose a landing site on Mars?** *(Spectroscopy data can show us minerals that form in water, which means liquid water was at a location in the past. That location would be a good landing site.)*

2. Ask: **When might measuring reflected light (spectroscopy) help us?** *(Paint color matching; at crime scenes; identifying crops or minerals on Earth, etc.)* Consider returning to learners' ideas at the start of the next activity.

3. Say: **Spectroscopy is used to identify unknown materials on Earth, on other planets, and in distant galaxies. This tells us something important about the universe: it is all made of the same stuff and science works the same everywhere. We can use our knowledge of science and engineering on Earth and know that it also applies to everywhere else in the universe!**

4. Ask: **What questions do you still have?** If there are unanswered questions on the *Our Ideas* poster, encourage learners to do some research on their own using these resources.

5. Say: **Good job working as scientists today! Now you are prepared for next time, when you will put together all the information you have gathered to choose a site for the rover to land on Mars. Remember, the process you are following is like the process NASA uses to choose landing sites.**

After the Activity

1. Clean up:

    - Keep the *Our Ideas* poster for use in Activity 7.
    - Collect the supplies from each station: audio player, *Science Activity 6 Data Packet* and tactile graphs, *Mineral Fingerprints Handout* and tactile graphs, and station signs. Save for use in future activities.

2. Plan ahead for Science Activity 7. See Activity 7 Materials Preparation on p. X.

3. Take time to reflect on the following educator prompt: **How did you help learners apply what they learned about minerals and light in the previous Activity?**

Remote Sensing Unit Resources QR code leads to resources available for this unit. QR code
https://planets-stem.org/topic/remote-sensing

Science Activity 6

Mineral Fingerprints Station Assembly Instructions

There will be six stations that run concurrently, three stations for each landing site (Gale Crater and Jezero Crater).

Each of the materials lists below is for one setup; however, to accommodate 24 learners, each landing site station needs three setups. Prepare and include the tactile spectra models (instructions on p. X) with each station, if you think learners would benefit from these.

To assemble each Station, arrange all the materials for a station on a table or desk, leaving room for learners to move between the stations.

Gale Crater Station materials for one setup:

- Mineral Fingerprints Data audio files (6 files)
- Gale Crater Unknown Minerals audio files (4 files)
- audio player with headphones
- cleaning wipes
- *Gale Crater Data*
- *Mineral Fingerprints Handout*
- tactile model of *Gale Crater Data* (optional)
- tactile model of *Mineral Fingerprints Handout* (optional)
- Gale Crater station sign

Jezero Crater Station materials for one setup:

- Mineral Fingerprints Data audio files (6 files)
- Jezero Crater Unknown Minerals audio files (3 files)
- audio player with headphones
- cleaning wipes
- *Jezero Crater Data*
- *Mineral Fingerprints Handout*
- tactile model of *Jezero Crater Data* (optional)
- tactile model of *Mineral Fingerprints Handout* (optional)
- Jezero Crater station sign

Teaching Tip

If learners have their own devices and headphones and access to the internet, you can provide a QR code to each audio file. You could also provide links to the audio files and use a computer or tablet. Find a quiet area for the audio stations, if possible.

Mineral Station Signs

GALE CRATER

GALE CRATER

Mineral Station Signs

GALE CRATER

JEZERO CRATER

Mineral Station Signs

JEZERO CRATER

JEZERO CRATER

Science Share-Out Invitation

Mineral Fingerprints Handout

[Minerals Data Packet]

Science Activity 7: Destination Mars: Choosing a Landing Site and Preparing for the Science Share-Out

Educator Preview

Activity Snapshot

Learners combine multiple data sets made possible by technologies that engineers designed to choose a safe and scientifically interesting landing site for a Mars rover. They then prepare to share their findings with the whole group and with invited guests.

Timing	**Prep Snapshot***	**21st Century Skills Connection**
Get Ready and Team Up 10 min Choose a Landing Site and Prepare for the Share-Out 25 min Reflect 10 min **Total** **45 min**	Prep Time 40 min (several days in advance) Send Science Share-Out Invitations people from the community. **See Materials & Preparation for full info*	● Communication **Science Practices** ● Interpreting Data ● Constructing Explanations ● Communicating Information

Guiding Question
Which landing site on Mars do we recommend, and why?

Learners Will Do
Choose a landing site that is scientifically interesting and safe.

Learners Will Know

Choosing a site involves making tradeoffs.

Connecting Across Activities

Activity 6: Using Spectroscopy to Understand Mars	**Activity 7: Choosing a Landing Site and Preparing for Science Share-Out**	**Activity 8: Science Share-Out**
Last time, learners interpreted spectra to identify the types of minerals at each of the different landing sites. These graphs are the third set of data they will use to choose a landing site.	**Today**, they use the various kinds of data they have collected–landform images, topographic maps, and spectra–to choose a landing site.	**Next time**, they will share their findings.

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code
[link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster
- Audio mineral data from Science Activity 6
- Tactile *Mineral Fingerprints Handout* from Science Activity 6 (optional)
- Tactile version of the *Science Activity 6 Data Packet* (optional)
- Devices for listening to audio

For each small group

- *Data Packets* from Science Activities 2, 4, and 6
- *Landing Site Oval* from Science Activity 2

For each learner

- Science Notebook

For community members

- Science Share-Out Invitations

Activity 7 Materials Preparation (15 min)

Ahead of Time

1. Review the “In-Use Example” in the *Prep & Setup Guide* to help you think about what to add to the *Our Ideas* poster during the discussions in this activity.

2. If you have not already, send out Science Share-Out Invitations to invite people from the community, including families and friends of learners, to the Science Share-Out.

3. For reference,
    a. download the audio files for each spectrum and set up a listening station center for learners to refer to as they choose. Place one copy of the *Mineral Fingerprints Handout* and one copy of the *Science Activity 6 Data Packet* at the center.
    b. place tactile *Mineral Fingerprints Handout* and tactile *Science Activity 6 Data Packet* at a center that is accessible to all learners so they can refer to these as they choose.

In Your Space

4. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.

Pages for Activity 7

- *Make the Case for Your Site*, p. X

[RS_EDG_SCI_7_Make_the_Case_for_Your_Site_Thumbnail]

- *Data Packets*

[RS_EDG_SCI_2_Science_Activity_2_Data_Packet_Thumbnail]

- *Landing Site Ovals*

[RS_EDG_SCI_2_Landing_Site_Ovals_Thumbnail]

- *Mineral Fingerprints Handout*

[RS_EDG_SCI_6_Mineral_Fingerprints_Handout_Thumbnail]

Get Ready and Team Up (10 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** *(We interpreted spectra to identify unknown minerals at each potential landing site. We ranked the sites based on the number of minerals present that form in water*). Draw learners' attention to their findings about minerals on the *Our Ideas* poster.
2. Say: **Our challenge is to choose the best landing site to search for past liquid water.**
3. Refer to the *Our Ideas* poster*.* All questions related to this activity should have been answered. If there are unanswered questions, encourage learners to do some research on their own using the links on Learner Resources. Say: **When a mission to land on another planetary body gets to the point of picking a landing site, NASA pulls together large teams of people to narrow down locations. They examine a lot of different types of data to make a decision. Today, you will consider all the data you have collected–on landforms, topography, and minerals–and choose the landing site you decide is safest and most likely to have evidence of past liquid water.** Share the Guiding Question with learners aloud and write it on the *Our Ideas* poster (using multiple languages as needed): **Which landing site on Mars do we recommend, and why?**

Level Up!

Have learners find out more about picking the candidate landing sites for the Artemis III mission in "NASA Identifies Candidate Regions for Landing Next Americans on Moon." (5 min.)

4. Organize learners into groups of four and distribute Science Notebooks.

Choose a Landing Site and Prepare for the Share-Out (25 min)

Choose a Landing Site (10 min)

1. Say: **What are some things you have to think about when choosing a landing site?** *(The landforms, the minerals present, the landing site perimeter, the safety.)* Say: **In your groups, you will need to decide on one landing site. You will need to consider which site would offer the most interesting science but also consider the safety of the site. Sometimes one site might be the safest, but not the most interesting.** *(Use hand gestures as if you are weighing the options.)* **So you will have to consider or weigh all the factors and try to reach a decision that best balances all the factors. When you think about all of the factors and options, you are considering the compromise, or *tradeoff*, between site safety and interesting science**.

2. Say: **In your groups, review the data for (1) landforms, which you detected from images, (2) safety, which you found from topographic maps, and (3) minerals, which you detected from spectroscopy.** As you mention each type of data, refer to the Science Notebooks, the charts on the *Our Ideas* poster, or other shared documents from Science Activities 2, 4, and 6.

Support Thinking

Allow learners to reference the audio and tactile data as needed. If time permits, let learners research unanswered questions from the *Our Ideas* poster.

Teaching Tip

Before learners begin, consider suggesting roles that group members can fill, such as one member referring to observations from previous activities, another member tracing the landing oval on maps, and a third recording the group’s choices.

There is no “right” answer to which site to select. Gale Crater and Jezero Crater were both selected as landing sites for NASA rovers. If you opted to do the Level Up to include the Nili Fossae and Iani Chaos sites, both really were considered as possible landing sites, and Nili Fossae was a finalist in site selection for both rovers.

If all of your groups seem to be choosing the same landing site, you can gently encourage some groups to choose a different option, which will lead to more interesting discussion and debate.

Prepare for the Share-Out (15 min)

1. After about 10 minutes, say: **Once your group chooses a landing site, decide how you would like to share information about that site. You will share with the whole group and any invited guests.** Ask**: What are the important ideas you think we should share?** *(Our role as scientists; the problem of gathering information from a distance; the definition of remote sensing; questions we were trying to answer, the benefits of each site, the tradeoffs, etc.)* **How do you think we should share our findings?** *(Posters; drawings, mapping or graphing our findings; recording a video or audio message; staging a performance; writing a description, etc..)* Say: **If you want to, you can use the sentence frames on *Make the Case for Your Site,* page 30 in the Science Notebooks, to get started.**

2. As groups are working, help guide their thinking by asking one or more of the following questions: **What evidence can you use to help you choose your landing site? Which site do you think will be the most scientifically interesting? Why? Which is more important: site safety or interesting science? Why?**

Support Thinking

The Share-Out is a chance for learners to explain their thinking and reflect on what they learned about remote sensing throughout the unit. As a group, agree upon a structure for the Share-Out. Possible structures include the following:

- Storytelling: Groups use the evidence they've collected to tell stories about how their sites were formed and why they are the best site for the rover to visit.
- Gallery Walk: Groups stand at their stations and explain posters, graphs, maps, writings, drawings, audio or videos on small devices, or other artistic depictions of the site they believe should be selected.
- Pair-Share: Groups pair off and share their choices with one another.
- Screening: The whole group watches video or audio files that learners have created. If time permits, they can make slideshows or animations.
- Performance: Some people play scientists making recommendations and some are NASA professionals asking questions about the site. You can develop script cards to include adults in the play.
- Discussion: Learners and community members share their knowledge. You can write discussion prompts to lead this discussion.

Teaching Tip

Provide time for learners to practice their share-out in pairs or small groups.

Reflect (10 min)

3. Revisit the Guiding Question on the *Our Ideas* poster. Ask: **Which landing site on Mars do we recommend, and why?** Learners should refer to their own work to answer the question. Help learners to accept that other groups may have made a different choice, and that's fine as long as they can support their choice using the data they collected.

4. Say: **Sometimes, many sites seem interesting, so the evidence scientists use to explain their reasoning is important. A site may be "best" in terms of science, but not good for safety, so scientists need to consider tradeoffs. Important decision making requires looking at the problem in different ways, working as a group, and compromise.** Ask: **When might it be useful to work with others, consider a problem in different ways, and compromise?**

5. Say: **Good job working as scientists today! Now you are prepared for next time, when you will present to each other and to our guests. Remember, the process you are following is like the process NASA uses to choose landing sites.**

After the Activity

1. Clean up:

    - Keep the *Our Ideas* poster for use in Activity 8.
    - Collect the *Science Notebooks*, *Science Activity 2 Mars Landforms Data Packets*, *Science Activity 4 Mars Landing Site Topography Data Packets*, *Science Activity 6 Mineral Data Packets,* and *Landing Site Ovals*.
    - If you set up listening and tactile stations, collect the materials from each.

2. Plan ahead for Science Activity 8. See Activity 8 Materials Preparation on p. X.

3. Take time to reflect on the following educator prompt: **What methods did learners choose to present their ideas? How did you support multiple means of expression?**

Remote Sensing Unit Resources
QR code leads to resources available for this unit.
QR code
https://planets-stem.org/topic/remote-sensing

Science Activity 8: Sum It Up: Science Share-Out

Educator Preview

Activity Snapshot

Learners share their recommendations for the safest and most scientifically interesting Mars rover landing site.

Timing Get Ready and Team Up 5 min Science Share-Out 30 min Reflect 10 min **Total 45 min** **Level Up Activities** 5–30 min each	**Prep Snapshot*** Prep Time 40 min (several days in advance) Send Science Share-Out Invitations to people from the community. **See Materials & Preparation for full info*	**21st Century Skills Connection** ● Communication **Science Practices** ● Interpreting Data ● Constructing Explanations ● Communicating Information

Guiding Question

Which landing site on Mars do we recommend, and why?

Learners Will Do

Communicate Mars landing site choice to others and support the decision with evidence.

Learners Will Know

Using different types of remote sensing gives a more complete understanding of an area.

Connecting Across Activities

Activity 7: Choosing a Landing Site and Preparing for the Science Share-Out	Activity 8: Science Share-Out	Engineering Pathway
Last time, learners used the various kinds of data they collected –landform images, topographic maps, and spectra– to choose a landing site.	**This time**, they share their findings.	**Next time**, learners experience engineering related to this topic in the PLANETS Worlds Apart Engineering Pathway (optional).

Educator Resources

Access Science Activity resources using link or QR code. Educator background and videos are available online. More information is also available in the Introduction, pp. X–Y.

QR code [link]

Materials and Preparation

Materials

For the whole group

- *Our Ideas* poster
- Audio mineral data from Science Activity 6
- Devices for listening to audio
- Tactile *Mineral Fingerprints Data Handout* from Science Activity 6 (optional)
- Tactile version of the *Science Activity 6 Data Packet* (optional)

For each small group

- *Data Packets* from Science Activities 2, 4, and 6
- *Landing Site Oval* from Science Activity 2

For each learner

- Science Notebook

For community members

- Science Share-Out Invitations

Activity 8 Materials Preparation (15 min)

Ahead of Time

1. If you have not already, send out Science Share-Out Invitations to invite people from the community, including families and friends of learners, to the Science Share-Out.

2. For reference,
    a. download the audio files for each spectrum and set up a listening station center for learners to refer to as they choose. Place one copy of the *Mineral Fingerprints Data Handout* and one copy of the *Science Activity 6 Data Packet* at the center.
    b. place tactile *Mineral Fingerprints Data* and tactile *Science Activity 6 Data Packet* at a center that is accessible to all learners so they can refer to these as they choose.

In Your Space

3. Place the *Our Ideas* poster in a visible place in your learning setting or prepare to share it digitally.

Pages for Activity 8

- *Data Packets*

[RS_EDG_SCI_2_Science_Activity_2_Data_Packet_Thumbnail]

- *Landing Site Ovals*

[RS_EDG_SCI_2_Landing_Site_Ovals_Thumbnail]

- *Mineral Fingerprints Handout*

[RS_EDG_SCI_6_Mineral_Fingerprints_Handout_Thumbnail]

Activity Guide

Get Ready and Team Up (5 min)

Support Learner Differences

If learners are new to you or each other, have them share their names, name pronunciations, and other important parts of their identities. These introductions are important for all learners and can be especially relevant for Indigenous learners, multilingual learners, and learners with different physical abilities. You can also distribute index cards and have learners write anything they want you to know but do not want to share with the whole group, such as resources that will help them learn. Lead an inclusion activity that is appropriate for your group (a list of possible activities is available on p. X).

For more strategies to engage learners, refer to *Designing Instruction to Reach Diverse Learners*, pp. X–Y.

1. Ask: **If you did the last activity, what did you do and why?** (*We revisited the landform, topographic and spectroscopy data to choose the safest and most scientifically interesting site to land a rover on Mars. We prepared to share our findings with the group and invited guests*).
2. Remind learners of the Guiding Question on the *Our Ideas* poster: **Which landing site on Mars do we recommend, and why?** Say: **Today, you will present your choice to the group and invited guests.**
3. Organize learners into the same groups as the previous activity.

Science Share-Out (30 min)

1. Remind learners of the structure they have planned for the Share-Out. Say: **The Share-Out is a chance for you to display your ideas, explain your thinking, and reflect on what you learned about remote sensing throughout the unit.**

2. Provide time for learners to make any last-minute preparations.

3. When learners are ready, invite guests into the room and explain how the Share-Out will proceed. Carry out the steps of the Share-Out as the group has planned.

4. As they experience the Share-Out, invite families and other guests to think about their family, cultural, or other knowledge related to what they observe here today and share that knowledge with learners individually or during the event as a whole.

Reflect (10 min)

1. After all groups have shared, ask learners to reflect on the sites selected. Ask: **Did all groups agree on where the rover should land? Why or why not? Would you have made the same recommendation if you were missing some of the data from the packets? For example, how would your recommendation be different if you had no data about landforms?** *(We could not have chosen our site if we didn't know about its landforms, topography, and minerals. Using different kinds of remote sensing together gives a much more complete understanding of a site, much like how a person uses all their senses to understand the world, not just one.)*

2. Say: **Good job working as scientists today! The process you've followed is like the process NASA uses to choose landing sites.** Tell learners what really happened when scientists and engineers had to choose landing sites for prior Mars missions:
    - **NASA chose Gale Crater as the landing site for its Curiosity rover, which landed on Mars in 2012 and has been exploring ever since.**
    - **NASA chose Jezero Crater for its Perseverance rover. The rover launched in 2020 and landed in 2021.**

Level Up!

For more on Curiosity, share an exciting NASA video, *Curiosity's Seven Minutes of Terror*, about the challenges of landing Curiosity at Gale Crater. Learn more about the Curiosity rover and see pictures from inside Gale Crater. (30 min.)

If learners examined all four sites, add: **NASA also considered Iani Chaos and Nili Fossae as landing sites for Perseverance but ruled out both. Iani Chaos is too rough, and although both sites have water-related minerals, they lack water-related landforms.** (5 min.)

If you have time, show the image "Mars Probe Landing Ellipses," which compares landing ellipses for different Mars missions over time. (5 min.)

After the Activity

1. Clean up:

    - Collect the *Science Notebooks*, *Science Activity 2 Data Packets*, *Science Activity 4 Data Packets*, *Science Activity 6 Data Packets,* and *Landing Site Ovals*.
    - Decide if you want to keep the *Our Ideas* poster.
    - If you set up listening and tactile stations, collect the materials from each.
    - Reset the space in which you held the Share-Out.
    - Consider saving materials to use if you teach these activities again in the future.
    - Decide what to do with learners' designs and presentation materials.

2. Take time to reflect on the following educator prompt: **How did you create opportunities for interaction with community members? How can you do so in other situations in the future?**

Remote Sensing Unit Resources QR code leads to resources available for this unit. QR code
https://planets-stem.org/topic/remote-sensing

Glossary

Composition: What a surface is made of

Constraints: limits on a design

Criteria: things a successful design needs to do or have

CTX: Context Camera, a camera on the Mars Reconnaissance Orbiter

Fairing: The part that sits on top of the rocket and protects a spacecraft during launch

HiRISE: High Resolution Imaging Science Experiment, a camera on the Mars Reconnaissance Orbiter

Landform: a shape on the surface of a planetary body

Physical properties: The shape and texture of a surface

Resolution: The amount of detail in an image

Spectrometer: a technology that measures the amount of light reflected from an object at many different colors (wavelengths).

Spectroscopy: the study of how light of different colors behaves when it touches something

Spectrum: a range of colors

Technology: an object, system, or process designed by people to solve a problem

Topographic map: a representation of the shape of land in an area

Topography: the shape of land in an area