Science Activity 3: Mineral Fingerprinting

Educator Preview

Activity Overview

Youth interpret the spectra of reflected light to identify the water-based minerals at each of four potential landing sites, determining which location on Mars has the most evidence of past water.

Timing		**Prep Snapshot**	**21st Century Skills Connection**
Introduction	5 min	Prep Time 60 min	• Critical Thinking
Minerals and Spectroscopy	15 min	At least two days ahead, create tactile spectra graphs and allow them to dry.	**Science Practice**
Explore Data	35 min		• Analyzing & Interpreting Data
Reflect	5 min		
Total	**60 min**		

Guiding Question	**Youth Will *Do***	**Youth Will *Know***
How can interpreting mineral data help us choose a landing site on Mars?	• Interpret the unique spectral “fingerprints” of different minerals to identify them. • Apply their knowledge of which minerals are evidence of past water when evaluating landing sites.	• Spectroscopy measures how much light of different colors (both visible and invisible) is emitted by or reflected from a material. • There are many “colors” of light humans can’t see, but engineers build instruments to measure them.

Connecting Across Activities

In Science Activity 2, youth used LiDAR data to examine topography. In this Activity, they use another remote sensing technology, spectroscopy, to identify minerals at different landing sites. In Science Activity 4, they will use the various kinds of data they have collected to choose a landing site.

Educator Resources

Access Activity resources using link or QR code.

Activity Resources

QR code leads to resources available for this Activity.

https://planets-stem.org/**betars-activity-s3**/

Family Connection

If time permits, have youth ask the following question to their Elders, families, or mentors before the Activity:

Q: Can you tell me a story about identifying parts of nature that were important to you, like plants, rocks, minerals, or animal tracks?

Materials and Preparation

Materials

For the whole group

- Assorted rocks and minerals, small, such as gravel mixture
- *Minerals Chart* or shared document (save for use in Activity 4)
- Audio files for Mineral Fingerprints Data
- 4 audio player(s) with headphones (or youths' 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)
- 8 copies of each image in *Science Activity 3 Data Packet*
- 6 additional copies of Spectra Pages in *Science Activity 3 Data Packet* (if planning to make Tactile Spectra Models)
- 8 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* (2 signs per station)

Assembled tactile models:

- 2 copies of tactile models of *Gale Crater Data* (3 spectra and 1 map), pages 44 – 53 from *Science Activity 3 Data Packet* (6 total spectra models) (optional)
- 2 copies of tactile models of *Iani Chaos Data* (2 spectra and 1 map), pages 54 – 61 from *Science Activity 3 Data Packet* (4 total spectra models) (optional)
- 2 copies of tactile models of *Jezero Crater Data* (4 spectra and 1 map), pages 62 – 69 from *Science Activity 3 Data Packet* (8 total spectra models) (optional)
- 2 copies of tactile models of *Nili Fossae Data* (3 spectra and 1 map), pages 70 – 77 from *Science Activity 3 Data Packet* (6 total spectra models) (optional)
- 8 copies of tactile spectra models of *Mineral Fingerprints Data* (6 spectra), double sided, in color, if possible (48 total spectra models, or reduce number and share) (optional)

Supporting Learner Differences

You may also want to create tactile models of the graphs on *Electromagnetic Spectrum*, *Aspen Leaf Spectra*, and *What Color Is Olvine?*, pages 17, 20, 21, and 23 in the Science Notebook.

For each youth

- Science Notebook

Activity 3 Materials Preparation (60 min, at least two days ahead)

Teaching Tip

There will be four stations that run concurrently, one for each landing site (Gale Crater, Iani Chaos, Jezero Crater, and Nili Fossae). Each site will include visual and audio files for each of the six minerals in *Mineral Fingerprints Handout*. Ensure there are enough materials at each station for one quarter of the youth to be working in each, or two groups of four per station.

To reduce the amount of color printing, you (or youth) can color in the visible light spectrum on the spectral graphs.

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

1. See *Mineral Fingerprints Stations Assembly Instructions* on pages 73 – 74 for instructions on using the materials to set up the tactile and audio stations.

2. Determine how youth 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 youth the QR codes or links to the files if you plan to have youth access audio files online.

3. Make copies of *Mineral Fingerprints Handout, Science Activity 3 Data Packet,* and the *Mineral Station Signs*. (Note: Printed data packets are included in kit for beta test.)

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 in *Mineral Fingerprints Handout* (6 graphs) and the *Science Activity 3 Data Packet* (12 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. This will give you enough materials for one group of four. Repeat as necessary so you have enough for half the youth in your program to access the tactile graphs at once. Print, fill, and copy a Science Showcase flyer for each youth to send home at the end of the Activity in preparation for the Science Showcase in Activity 4.

Supporting Learner Differences

Many youth will benefit from a tactile version of the spectroscopy data. However, if time is short, tactile graphs are optional. For two setups per mineral station site, you will need to create 24 tactile spectral graphs, pages 44 – 53, 54 – 61, 62 – 69, and 70 – 77 in the *Science Activity 3 Data Packet*. You will also need to create tactile spectra of the six known minerals, pages 2, 6, 10, 14, 18, and 22 in *Mineral Fingerprints Handout*. 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 across the sites. If appropriate, solicit help. If appropriate, create tactile models of *Electromagnetic Spectrum, Aspen Leaf Spectra*, and *What Color Is Olivine?,* pages 17, 20, 21, and 23 in the Science Notebook.

Activity Guide

Guiding Question: How can interpreting mineral data help us choose a landing site on Mars?

Post the question somewhere accessible, such as on chart paper or a shared document, so that youth can refer to it throughout the activity.

Introduction (5 min)

1. If you sent youth home with the Family Connection question, ask:

   Q: Did anyone talk with their families about identifying parts of nature? If so, is there anything you would like to share?

   A: Accept all responses. Possible responses include plant identification for medicine, dyes, or avoiding poisonous or harmful plants like poison ivy; animal tracking for hobby or hunting; and rock identification for building materials.

2. Pass out Science Notebooks. Have youth think back to the previous activity. Ask:

   Q: As scientists, what are we trying to find out? What data have we examined so far?

   A: We are trying to find the best location to land a rover on Mars so that we can learn about things like whether there was liquid water or life there in the past. So far, we have explored visual data and topographic maps to learn about landforms on Mars.

Supporting Youth Thinking

If youth 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.

3. Explain that there are not any plants on Mars, but there are a lot of rocks and minerals. Some rocks and minerals only form under certain conditions: for example, in water. So, knowing which minerals are at each landing site helps us understand whether that site once had water. Share the Guiding Question:

   Q: How can interpreting mineral data help us choose a landing site on Mars?

4. Explain that each kind of mineral forms in a certain way. Some minerals form only in water. Tell youth that they will be provided with a list of minerals and how they form, and they will learn how to identify minerals that form in water.

Minerals and Spectroscopy (15 min)

1. Organize youth, or have them organize themselves, into groups. Give each group some rocks and minerals to examine for several minutes. Ask:

   Q: How might we figure out what kinds of rocks and minerals these are?

   A: Accept all responses. Possible responses include touching them, looking at them, weighing them, shining light on them, doing tests on them, thinking about where they were found, and showing them to a friend, family member, or other person in the community.

Supporting Youth Thinking

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

2. Explain that since 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 technology on spacecraft orbiting Mars, and on rovers on the surface.

   One technology that engineers have designed measures the colors of light reflected from an object. We think of light as colorless, but even "white light" is made up of many different colors—even some "colors" that are invisible to human eyes! Because this technology measures a range of colors, or a **spectrum**, it is called a ***spectrometer***. Scientists often display the data collected by spectrometers in a graph. Each material has a unique graph that scientists can use like a fingerprint to identify the material. As scientists, we can interpret the shapes of different graphs to identify the minerals on Mars.

Supporting Youth Thinking

This Activity uses the term *color* rather than *wavelength* to simplify vocabulary, but the terms are not synonymous. Color refers to those wavelengths that are visible to the human eye. Many other wavelengths lie below and above visible light on the electromagnetic spectrum. If youth are ready and you are comfortable, you can discuss the distinction between the concepts.

3. Invite youth to review *Electromagnetic Spectrum*, pages 17 – 18 in their Science Notebooks. Let them know that this diagram describes the light that comes from the Sun, both visible and invisible, that spectrometers measure.

Supporting Learner Differences

If appropriate, distribute tactile models of *Electromagnetic Spectrum*, *Aspen Leaf Spectra,* and *Olivine Spectrum*, pages 17, 20, 21, and 23 in the Science Notebook.

Connecting Across Activities

This unit's Science Series Activities challenge youth to design technologies similar to spectrometers that will help scientists distinguish between different materials.

4. Ask youth to make observations of *Aspen Leaf Spectra*, pages 19 – 21 in the Science Notebook, which show the spectra of aspen leaves in the summer and fall. Guide youth to understand that the graphed lines show how much light of each color is reflected from (or bounces off) each leaf. Where the line is high, that color of light is mostly reflected. Remind youth that human eyes perceive objects as being different colors based on how much of each color of visible light they reflect. Ask:

   Q: Where on the graph does the summer aspen leaf reflect the most light? What color will the summer leaf be, to human eyes?

   A: The summer aspen leaf reflects the most light in the green range, which is why it appears green to human eyes.

   Q: Where on the graph does the fall aspen leaf reflect the most light? What color will the fall leaf be, to human eyes?

   A: The fall aspen leaf reflects the most light in the yellow, which is why it appears yellow to human eyes.

5. Point out that the rainbow representing the part of the electromagnetic spectrum that is visible to humans is only a tiny part of the light that is measured by spectrometers. Draw youths' attention to the part of the spectrum that is beyond the rainbow, or visible spectrum. This light cannot be seen by human eyes, however, the line on the graph lets scientists know that some other kind of light data—other "colors" of light—are being reflected.

   Because scientists need to detect light that humans cannot see, they work with engineers to design technologies that can capture this type of information. Data about the "invisible light" can be represented by lines on a graph, but it can also be represented using sounds. The pitch of the sound lets scientists know how much light is reflected from the object.

   Let youth know you will play the audio files of the spectra for the two leaves. Before you play them, let them know the following information:
   - The pitch of the sound through time matches how much light is reflected as you go from left to right on the spectrum 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.

6. To practice, ask youth to listen to and compare the audio file of the first leaf spectrum to the audio file of the second leaf spectrum while exploring the graphs in their Science Notebooks. Encourage youth to trace the graphs with their fingers as they listen to the sounds. Play the two files a few times. Ask:

   Q: What differences do you notice between the sound of the first leaf spectrum and the sound of the second leaf spectrum?

   A: The second leaf audio is higher in pitch. The first leaf audio is lower in pitch. Both have a little bump and go back down at the end.

7. Let youth know that spectrometers gather information about any object, including minerals, like the ones they explored earlier. Ask youth to observe the spectrum on *What Color is Olivine?* on pages 22 – 23 of their Science Notebooks. Ask:

   Q: What do you notice about the spectrum of light reflected by a mineral called olivine? What color will olivine be to human eyes?

   A: In the colors visible to humans, olivine reflects more green than other colors, so it will appear green to human eyes.

   Tell the youth you are going to play them the audio file of a mineral called olivine, so they can compare it to the sounds of the leaves. Invite youth to listen to the audio while exploring the graphs in their Science Notebooks. Play the audio file of olivine. Ask:

   Q: Is olivine's spectrum more like the green leaf or the yellow fall leaf? What color do you think olivine appears to be?

   A: Its spectrum is more like the green leaf's spectrum (first leaf spectrum), so olivine probably appears green.

Note

Spectrometers are very important instruments and are part of dozens of past, present, and future NASA missions. Almost everything we know about the universe beyond Earth is because of spectroscopy, the study of how light of different colors (wavelengths) behaves when it touches something. Some of the light from distant objects in the universe travels toward us. We can see this light when we go outside and look up on a clear night. Some of this light goes into scientific instruments like spectrometers, which separate the light into its different colors. This allows astronomers to determine how stars and galaxies move through space, what they are made of, how old they are, and how hot they are. And planetary scientists study sunlight that bounces off other planetary bodies in our solar system, which allows them to determine what the objects are made of, for example, what minerals they have, or whether there is water or ice on the surface.

Supporting Youth Thinking

If time permits, allow youth to explore electromagnetic radiation through direct experience with objects such as prisms or heat lamps. Youth 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)*.

Contrast LiDAR and spectroscopy. Explain that while LiDAR measures the *time* it takes for light 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 wavelengths/colors.

If time permits, support youth understanding of spectrometers by having them build their own spectrometers or explore resources about spectrometers before introducing the term *spectrometer*.

To support youth understanding of the word *spectrometer*, explain that it comes from roots *spec*, meaning "to observe," and *meter*, meaning "measure." Have youth 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).

Teaching Tip

If you are short on time, this is a good stopping point. You can introduce the Mars Spectroscopy data in another session. Be sure to remind youth how to interpret the audio and visual spectral graphs at the beginning of the session.

Explore Data (35 minutes)

1. Let youth know that engineers designed a spectrometer that is onboard a spacecraft orbiting Mars. This device has measured the light reflecting off minerals at each landing site location. Youth are now ready to interpret this spectroscopy data to find out if there are any minerals that form in water at each of the four possible landing sites.

2. Explain Site Data Stations:
    - Let youth know you have set up stations around the room. Each station represents a landing site (Gale Crater, Iani Chaos, Jezero Crater, and Nili Fossae).
    - Each landing site station includes audio files and spectroscopy data representing the known spectra of six different minerals. Show youth the *Mineral Fingerprints Handout*. Point out that some of these minerals are formed in water (nontronite, kieserite, kaolinite, and gypsum) and some are not.
    - Each site also includes a map showing the location of some unknown minerals at that landing site. Youth need to identify these minerals using their spectroscopy data.
    - Youth should use the *Mineral Fingerprints Data* audio files and spectroscopy data to identify the unknown minerals at each site.
    - Youth should record their findings on *Sites with Minerals*, pages 24 – 25 in their Science Notebooks, and rank the sites based on how many minerals that formed in water are present.
    - Invite youth to take turns visiting each Site Data Station in pairs, and to identify the minerals.

Supporting Youth Thinking

To support youth understanding, you can show or describe the Mars Reconnaissance Orbiter (MRO) and the Compact Reconnaissance Imaging Spectrometer for Mars (CRISM) instrument using Activity 3 Resources.

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

3. Invite youth to visit the centers to use spectroscopy data to help them find the best landing site on Mars. Remind them to look for minerals that form in water because they might indicate evidence of past water (and therefore conditions for life).

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

4. Have groups record the minerals found at each site on *Sites with Minerals*, pages 24 – 25 in their Science Notebooks, and to rank the sites according to how many minerals that form in water they have. If necessary, suggest roles that group members can fill, such as referring to observations, moderating discussion, and recording the group's choices. Allow youth to post their findings in a location that everyone can access, such as chart paper or a shared document.

Supporting Learner Differences
To make this Activity more challenging, have youth 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.

If youth are pursuing the bonus challenge of searching for volcanic activity from Science Activity 1, have them consider the volcanic minerals at each site.

5. As youth explore, ask:

Q: What additional information do you gain by identifying minerals using audio as compared to the visual and tactile models?
A: Accept all responses. A possible response is that it is easier to notice certain aspects of the data in one form rather than another.

Note
The patterned areas on the mineral maps in the *Science Activity 3 Data Packet* are idealized and simplified, but in most cases, they are based on actual observations of these locations on Mars. The minerals listed really are at these locations!

Reflect (5 min)

1. Ask groups to reflect on the process of analyzing mineral spectra by asking one or more of the following questions:

   Q: Which stations provided you with the most information about minerals?
   A: Accept all responses.

   Q: Which stations were most enjoyable for you?
   A: Accept all responses.

   Q: What was most challenging for you?
   A: Accept all responses.

2. Restate the Guiding Question:

   Q: How can interpreting mineral data help us choose a landing site on Mars?
   A: Mineral data from light can show us what kinds of minerals are present, including minerals that form in water. Finding minerals that form in water means water was at a location in the past, so that location would be a good landing site.

3. Summarize youth's findings by discussing which minerals are present at each site. Record their ideas on the *Minerals Chart* or a shared document that is accessible to the whole group. Ask:

   Q: Using the information you gathered about minerals, which sites do you think might have had water in the past?
   A: Responses will vary. All four sites have minerals that form in water.

Note

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

Gale Crater: Olivine, Nontronite, Kieserite, Gypsum

Iani Chaos: Pyroxene, Kieserite, Gypsum

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

Nili Fossae: Olivine, Pyroxene, Nontronite (forms in water)

4. Remind youth they are following a site selection process that is very similar to the process NASA scientists have used in past and will use in present and future missions. Let them know that next time, they will put together all the information they have gathered to choose a site for the rover to land on Mars.

After the Activity

1. Plan ahead for Science Activity 4. See Activity 4 Materials Preparation on page 88.

2. Take time to reflect on the following educator prompt:

   Q: How did you connect the topics in this activity, such as minerals and colors of light, to youth's 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.

https://planets-stem.org/**betars-unit-landing-page/**

Science Activity 3

Mineral Fingerprints Station Assembly Instructions

There will be four stations that run concurrently: one station for each landing site (Gale Crater, Iani Chaos, Jezero Crater, and Nili Fossae). Each station will have two setups, for a total of eight setups.

Each of the four materials lists below is for one setup; however, each landing site station needs two setups, so that two groups of four youth can work at each station at the same time. Prepare and include the tactile spectra models (instructions on page 59) with each station, if you think youth would benefit from these.

To assemble each Station, arrange all the materials for a station on a table or desk, leaving room for youth to move between the stations. Each *Mineral Station Sign* printout has two signs; cut the page in two and post one sign at each setup, where it is clearly visible to youth.

Gale Crater Station materials for one setup:

• Mineral Fingerprints Data audio files • Gale Crater Unknown Minerals audio files (3 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 Data* (optional) • Gale Crater station sign

Iani Chaos Station materials for one setup:

• Mineral Fingerprints Data audio files • Iani Chaos Unknown Minerals audio files (3 files) • audio player with headphones • cleaning wipes	• *Iani Chaos Data* • *Mineral Fingerprints Handout* • tactile model of *Iani Chaos Data* (optional) • tactile model of *Mineral Fingerprints Data* (optional) • Iani Chaos station sign

Jezero Crater Station materials for one setup:

- Mineral Fingerprints Data audio 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 Data* (optional)
- Jezero Crater station sign

Nili Fossae Station materials for one setup:

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

Teaching Tip

If youth 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

IANI CHAOS

IANI CHAOS

Mineral Station Signs

JEZERO CRATER

JEZERO CRATER

Mineral Station Signs

NILI FOSSAE

NILI FOSSAE

You're invited to the Science Showcase

COME SEE YOUR YOUNG SCIENTIST SHARE THEIR RECOMMENDATIONS FOR NASA

We will also invite you to share something you know, or an experience you've had, that relates to science and technology

Date: ________________________

Time: ________________________

Location: ________________________

PLANETS