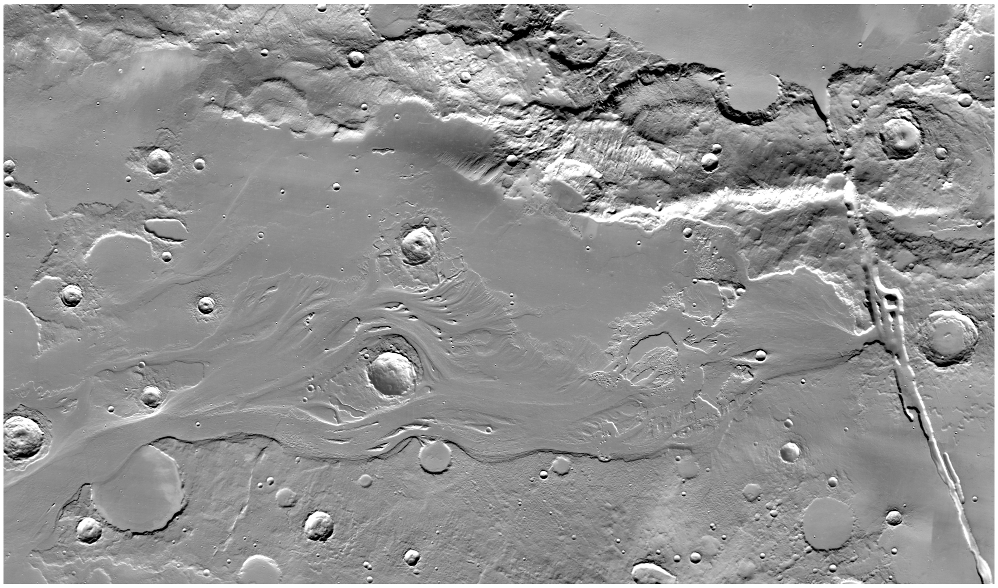
National Aeronautics and Space Administration

Question Mars

Grades: Middle School **Prep Time: ~10 Minutes** **Lesson Time: 3 Hours**



WHAT STUDENTS DO: Generate a Research Question and/or Hypotheses for Mars

In this activity, students step into the shoes of real planetary scientists and experience one of the first steps in the process of science; developing hypotheses and testable questions. Students are tasked with using the topic identified in the Mars Image Analysis activity to establish hypotheses and a question about the surface of Mars. The purpose of this lesson is for students to use a critical thinking and a collaborative approach to scientific research in planetary geology. Using scientific observations and inferences students will:

- Generate a "big picture" question related to Mars;
- Generate hypotheses related to Mars geology; and
- Generate a research question related to Mars geology based on scientific observations.

NRC FRAMEWORK / NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES (IO)
WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT? *NRC Core Question: ESS1: Earth's Place in the Universe* **How do people reconstruct and date events in Earth's planetary history?** *NRC ESS1.C: The History of the Planet Earth*	*Students will be able to* **IO1: Generate** a research question and testable hypothesis based on observations of phenomena and credible information that can be investigated to describe the natural world patterns in and/or evidence about Martian geology, past or present.

See Section 4.0 and Teacher Guide at the end of this lesson for details on Instructional Objective(s), Learning Outcomes, Standards, & and Rubrics.

1.0 Rationale

Question Mars is intended to be a follow on lesson to the Mars Image Analysis. In Mars Image Analysis, students learn how to make strong scientific observations in addition to becoming acquainted with the geology of the planet Mars. At the end of the lesson students establish a topic of interest for their research. This topic will be necessary for the Question Mars lesson. This lesson is designed to mirror the process many scientists go through in establishing a research question. It is important to note that these scientists have had many years of experience in the field and typically come to a research question in a very organic and chaotic way. This lesson is structured to grow novice experience so that they too may one day ask questions in this same organic way.

In Question Mars, we will focus primarily on hypothesis development and question writing. We will attempt to avoid the pitfalls of question writing by looking at hypotheses. A distinction that needs to be made with students from the traditional scientific method to the iterative process of science is that more often than not, scientists develop hypotheses and questions simultaneously. Examples have been provided in the student guide. The intention is for students to see the shift in their own thinking. They should recognize from the examples that the scientist generated an hypothesis with their observations at the same time as they are asking questions.

Starting the Lesson:
All science begins with a question or a hypothesis. Keep in mind that it is a natural part of science to refine or even change your question as your research progresses. The process of science continues with designing an experiment to answer that question and test your hypotheses. For this activity, the focus is on generating a high-quality research question and hypothesis. Students will need the Mars Image Analysis materials for this lesson and should be grouped in small groups (approximately 3-4) for brainstorming and development of hypotheses and questions.

2.0 Materials

Required Materials

<u>Please supply resources from Mars Image Analysis Lesson (per group of students)</u>:

- Completed Mars Image Analysis Student Data Log
- Completed Mars Image Analysis Observation Sheets
- Completed Mars Image Analysis Topic Selection Sheets
- Mars Orbital Laser Altimeter (MOLA) maps

Facility

- A room or computer lab where students can easily access *JMARS for MSIP*

<u>Please Print</u>:

From Student Guide:

(A)	Introduction	– 1 per student
(B)	Questions and Hypotheses	– 1 per student
(C)	Identifying the Big Picture Question	– 1 per student
(D)	Identifying the Explanations	– 1 per student
(E)	Writing a Research Question	– 1 per student
(F)	Writing a Testable Hypothesis	-- 1 per student
(G)	Reflections	– 1 per student

 NGSS Teacher Tip: Print the *(T) Reflection of Science and Engineering Practices* on blue paper and *(T) Reflection Crosscutting Concepts* on green paper to match the color-coded posters and standards.

Optional Materials

From the Alignment Document:

(H) Questions and Hypotheses Sample Answers
(I) Evaluation Criteria Rationale
(J) “Question Mars” Assessment Rubrics
(K) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types

NGSS Materials:

“A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas” (NRC, 2012), also known as the Framework, articulates a vision of exemplary science instruction based upon current research. This vision centers on 3-dimensional learning in which Disciplinary Core Ideas, Science and Engineering Practices, and Crosscutting Concepts in science and engineering

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are coherently integrated in instructional design. It isn't enough, however, that students engage in the Practices as they develop a deep understanding of the Core Ideas. Students must also be cognitively aware of what they are doing and what the Practices are. The reflection assignment will engage students in thinking about the Practices, about what those Practices are, and how the Practices relate to doing science.

This lesson will assist you in integrating this activity and will suggest resources.

Please Print:

NGSS Practices Poster
NGSS Crosscutting Concepts Poster
NGSS Understanding about the Nature of Science Poster

Please Read:

Appendix F – Science and Engineering Practices in NGSS
Appendix G – Crosscutting Concepts
Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

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3.0 Vocabulary

Analyze	consider data and results to look for patterns and to compare possible solutions
Big Picture Question	general/overarching questions that are typically asked based on scientific observations
Data	facts, statistics, or information
Explanations	logical descriptions applying scientific information
Inquiry	a method of learning scientists use, which includes observing, **questioning**, examining what's already known, planning investigations, using tools to gather, analyze, and interpret data, proposing **hypotheses** and predicting results, and communicating findings (derived from NSES, 1996)
Hypothesis	a possible explanation defining a relationship between features and geologic processes, must be testable
Mission	a spacecraft designed to explore space, seeking to answer scientific questions
Observations	specific details recorded to describe an object or phenomenon
Orbiter	a spacecraft designed to explore space, seeking to answer scientific questions
Planet	a sphere moving in orbit around a star (e.g., Earth moving around the sun)
Research Question	a specific testable question based on careful observations of phenomena

4.0 Procedures

STEP 1: ENGAGE (~30 minutes)
Review Examples

A. At the beginning of the lesson very briefly tell students that scientists and engineers engage in certain practices when they are doing science or engineering and certain fundamental ideas are applicable to all science and engineering, called crosscutting concepts.

B. Provide either wall posters (11 x 17 format) or individual handouts (8.5 by 11 format) briefly describing the Practices and Crosscutting Concepts (be sure to include the Nature of Science also).

C. Tell students that they will be asked to identify if they do any of these practices at the end of the activities.

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 NGSS Teacher Tip: The descriptions of the Practices and Crosscutting Concepts on the poster or handout are brief; therefore, you may wish to become more familiar with the Crosscutting Concepts and the Understandings about the Nature of Science. You can get very good information from the Next Generation Science Standards (NGSS) web site. Recommended are *Appendix F – Science and Engineering Practices in NGSS, Appendix G – Crosscutting Concepts*, and *Appendix H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards.* These resources will help you to assist your students if they say that they don't understand the Practices, Crosscutting Concepts, or the Nature of Science. Also, in the Alignment document provided for this lesson the instructional designers have indicated the Crosscutting Concepts they have determined to be most appropriate.

D. Ask students to consider the following using the Think, Pair, Share model:

a. How do you think scientists determine what they are going to research?
b. What do you think is the first step for scientists when they begin to design their investigation?

E. Give each student *(A) Introduction and (B) Questions and Hypotheses* worksheets, pages 1 and 2.

F. As a class, review (A) *Introduction* to explain that scientists don't use a contrived process of developing a question and an hypothesis, but instead they make observations that guide their hypotheses and their questions.

G. Examine page 1 of *(B) Questions and Hypotheses* to define terms. Ask students to think, pair, share the similarities and differences between the types of questions.

H. Share the examples from page 2 of *(B) Questions and Hypotheses* to establish an example. Engage in conversations with the students about these examples to ensure they understand the difference between the big picture question, hypothesis, and research question.

STEP 2: EXPLORE (~45 minutes)
Identify the "Big Picture" Question

A. Give each student pages 3 and 4 of *(B) Questions and Hypotheses* to use a guide for their initial questioning.

B. Explain that the prompts provided are not the only prompts students can use, but these cover the major types of question asked while making observations.

C. Review the definition of "Big Picture" questions

a. Remind students that these big picture questions are important questions, but are not research questions. These are very broad questions that require a significant

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amount of research to answer.

b. In this case, the students will be investigating one small aspect of their big picture question.

D. Give students the opportunity to work together in a group for brainstorming to complete the worksheets. As a team, the students will need to make decisions, so debate and collaboration will be extremely important.

STEP 3: EXPLAIN (~75 minutes)

Develop explanations

A. Give each student *(C) Identifying the Big Picture Question* and direct students to get out completed Student Data Log, Observation Sheets, and Topic Selection Sheets from the Mars Image Analysis lesson

B. Explain that students will begin developing explanations for their big picture questions. These will eventually be hypotheses, but for now, they will most likely just be ideas.

C. Review the prompts on page 1 of *(C) Identifying the Big Picture Question* and give examples of questions.

D. Explain to students that they may add more questions at the bottom of the page.

E. Allow groups the time to complete page 1.

F. Direct students to page 2 of *(C) Identifying the Big Picture Question* and give them time to narrow their questions down to their top 2 choices.

G. Students will need the opportunity to work in JMARS for MSIP to check that these explanations have measurable attributes and data is available.

H. Remind students that they will need to make decisions together, so debate and collaborations are extremely important.

I. Organize students into groups of size and composition you know to be most effective.

J. Hand out *(G) Reflections*.

K. Allow discussion for 10 – 15 minutes.

L. Ask each group to share its best thinking about which Practices and Understanding of Nature of Science were done, when it was done, and what the group's reasoning was for this. Record the results from each group in columns on the board.

 Teacher Tip: The most important part of these activities is to engage students' thinking about the Practices, Crosscutting Concepts and the Nature of Science. The emphasis is on the rationale the students provide rather than what Practices or Crosscutting Concepts were identified in the Alignment document. Be prepared to ask questions to elicit more complete reasoning for the group's decision. Allow discussion if groups do not initially agree. The discussions will help to develop deeper understandings.

STEP 4: ELABORATE (~30 minutes)

Write hypothesis and research question.

A. Give students page 1 of *(D) Identifying the Explanations* and tell them that their team needs to choose one big picture question for the group.

B. Once the group has reached consensus, they should write the question on page 1 and proceed to brainstorming explanations.

C. Give students pages 2 and 3 of *(D) Identifying the Explanations* and explain that they will use JMARS to see if there are tools available to test their explanations.

D. Using computers or iPads, give students access to JMARS for MSIP to check that these explanations have measurable attributes and data is available. They should record information in the chart of page 2 of *(D) Identifying the Explanations* and page 3 to narrow down possible explanations worth investigating.

E. Working as a group, students should share their top explanations and choose one for a primary hypothesis for the group.

F. Give students *(E) Writing a Research Question* and explain that these questions will need to be testable and that they will need to establish what will be measured in the experiment to learn if their explanation is true.

G. Refer to the lists of possible variables (in a simplified form) provided on page 1. Explain that research questions are not limited to these variables. These are a guide to move the in the right direction.

H. Working individually, give students time to complete both pages.

Teacher Tip: You will need to inform students how much time they will have to complete the entire research project so they can evaluate their questions. You may want to write the time in the chart on page 2 of *(E) Writing a Research Question*

I. Direct students to regroup and complete page 3 of *(E) Writing a Research Question*

J. See the final page of the Teacher's Guide for the rationale on the evaluation criteria.

STEP 5: EVALUATE (~30 minutes)

Write testable hypothesis.

A. Give students *(F) Writing a Testable Hypothesis* and review instructions to write a formal hypothesis.

Teacher Tip: The "if.....then...." statement has been provided as a guide, but is not 100% true in all cases. There is no need to use it if it doesn't make sense.

B. By the end of this sheet, students should have a final research question and a matching, testable hypothesis

Student Sheet #1 (~30 minutes)
Questions and Hypotheses

The intention of this sheet is to help students understand that scientists don't use a contrived process of developing a question and an hypothesis, but instead they make observations that guide their hypotheses and their questions. Examples have been provided for students to work with and to establish a model. It would be helpful to have conversations with the students about these examples to ensure they understand the difference between the big picture question, hypothesis, and research question.

Student Sheet #2 (~45 minutes)
Identifying the Big Picture Question

These sheets are provided to give students a guide for their initial questioning. The prompts provided are not the only prompts students can use, but these cover the major types of question students will ask while making their observations. These big picture questions are important questions, but are not research questions. These are very broad questions that require a significant amount of research to answer. In this case, the students will be investigating one small aspect of the their big picture question. Give students the opportunity work together in a group for brainstorming. As a team, the students will need to make decisions, so debate and collaboration will be extremely important.

Student Sheet #3 (~45 minutes)
Identifying the Explanations

In this sheet, students will begin developing explanations for their big picture questions. These will eventually be hypotheses, but for now, they will most likely just be ideas. These ideas will be critical in developing high quality research questions and hypotheses. Students will need the opportunity to work in JMARS for MSIP to check that these explanations have measurable attributes and data is available. As a class, they will need to make decisions together, so debate and collaboration will be extremely important.

Student Sheet #4 (~30 minutes)
Writing a Research Question

Students will use the explanations they have established in the previous sheet to create research questions. These questions will need to be testable and the students will need to establish what will be measured in the experiment to learn if their explanation is true. Lists of possible variables (in a simplified form) have been provided in the lesson, but research questions are not limited to these variables. These are a guide to move the students in the right direction. As a class, students will need to make decisions together, so debate and collaboration will be extremely important. See the final page of the Teacher's Guide for the rationale on the evaluation criteria.

Student Sheet #5 (~30 minutes)
Writing a Testable Hypothesis

Now that students have a research question, they can write a formal hypothesis. The "if.....then...." statement has been provided as a guide, but is not appropriate in all cases. There is no need to use it if it doesn't make sense. By the end of this sheet, students should have a final research question and a matching, testable hypothesis. As a class, they will need to make decisions together, so debate and collaboration will be extremely important.

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5.0 Extensions

As a homework activity, ask students to follow their curiosity about Mars. Ask them to go online (with parents or guardians, if their age suggests it), and ask "Dr. C" at least 3 questions about Mars. Have them write down the following url: http://marsdata1.jpl.nasa.gov/DrC

6.0 Evaluation/Assessment

Use the *(J) Question Mars Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric evaluates the activities using the Next Generation Science Standards.

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(A) Student Handout. Introduction

NAME:________________________________

Think, pair, share?

1. How do you think scientists determine what they are going to research?
2. What do you think is the first step for scientists when they begin to design their investigation?

All science begins with a question or an hypothesis. Some people refer to this as the "scientific method". The scientific method starts from questions or hypotheses we create based on our curiosity. We become curious about scientific observations we make. Professional scientists have questions about Mars they want to answer because they are curious, and so you will begin by investigating images from Mars. Keep in mind that it is a natural part of science to refine or even change your question as you research. The process of science continues with designing an experiment to answer that question and to test your hypotheses. Your goals through this lesson are:

- Follow your curiosity about Mars and create research questions and hypotheses using scientific observations;
- Evaluate your questions, making sure you have met the criteria for a scientific question;
- Realize that it's understandable to have "big picture" questions, but scientists (and you) need a specific focus or question to study; and
- Recognize that scientists contribute to a greater understanding of Mars through detailed research.

Photos Courtesy of NASA's Jet Propulsion Laboratory

(B) Student Sheet #1. Questions and Hypotheses (1 of 4)

NAME:______________________________

Did you know that many times scientists start with a big question in mind before they even have a research question or hypothesis? This often occurs as a result of very specific scientific observation, such as the observations you made in Mars Image Analysis. These big questions often lead to possible explanations. We call these explanations hypotheses. You may even already have a big question and an hypothesis about your topic! Below you will find a description of what is meant by a "big picture question," an hypothesis, and a research question.

Big picture questions are the initial questions a scientist will ask while making observations. When researchers observe a feature that is interesting or unique, they will often ask themselves "What is that? How did it form? Why does it appear this way? or Why is this different from other examples?" One of these questions will be the guiding question for the remainder of their research or even possibly their career!

Hypotheses often result from these "big picture questions." These are in the form of potential answers or explanations for the observation. There can be many working hypotheses that are an attempt to answer the question. Each hypothesis is specific to the data that will be collected. The hypotheses must be testable and falsifiable. This means an answer can be found and the answer can either support or refute the hypothesis.

Research questions are the best explanations to the big picture questions. Research questions are specific to the data that will be collected. Results from each research question can be pooled together to determine the best answer to the big picture question. Sometimes the hypothesis and research question are considered to be the same.

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(B) Student Sheet #1. Question and Hypotheses (2 of 4)

NAME:________________________________

Formation of Valles Marineris Hypothesis Example

Big Picture Question
How was Valles Marineris formed on Mars?

Hypothesis #1

If Valles Marineris was formed by water similar to the Grand Canyon, then water features will be evident inside of the canyon.

Hypothesis #2

If Valles Marineris was formed by tectonic plates and is a giant rift valley, then there will be evidence for other plate tectonic features on the planet.

Hypothesis #3

If Valles Marineris was formed as a stress fracture from the rising magma pressure below the Tharsis bulge, then there will be other large valles features also pointing away from the Tharsis region.

Research Question #1

Are water features, such as braided channels feeding the valley, and streamlined islands and oxbows found in the bottom of Valles Marineris?

Research Question #2

Can other tectonic features, such as trenches, island arcs, stratovolcanoes, and fault lines be found on the surface of Mars?

Research Question #3

Do all of the major valles features found around the Tharsis region point away from the center of the bulge (radially)?

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(B) Student Sheet #1. Question and Hypotheses (3 of 4)

NAME:________________________________

Below you will find 2 examples of stories from real research on Mars. These examples are stories about how the scientists came up with their questions for research. Read through each of these scenarios looking for the hypothesis and research question. The big picture question has been provided for you. Be prepared to share your findings with the class. Don't forget, sometimes the question may not be written in the form of a question, but more as a statement.

Gale Crater Landing Site of Curiosity (MSL) Rover

Whether life has existed on Mars is an open question that this mission, by itself, is not designed to answer. NASA's Mars Science Laboratory (MSL) mission will study whether the Gale Crater area of Mars has evidence of a past habitable environment. Curiosity will look for three conditions that are crucial for habitability; liquid water, a source of energy, and other chemical ingredients utilized by life, such as carbon, amino acids, nitrogen, phosphorus, sulfur, and oxygen.

Big Picture Question: Is there evidence of a past habitable environment in Gale Crater?

Hypothesis:

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Research Question:

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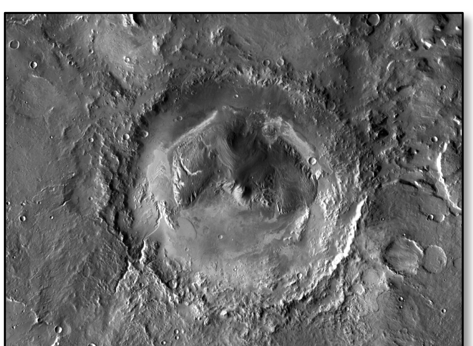


Photos Courtesy of NASA's Jet Propulsion Laboratory

Image left: Gale Crater

Image right: Curiosity Rover (MSL)

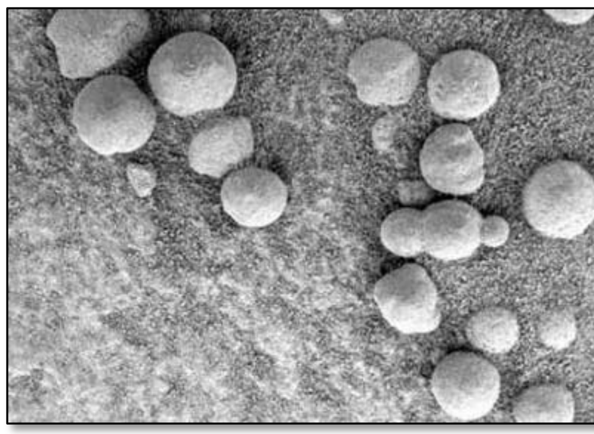
(B) Student Sheet #1. Question and Hypotheses (4 of 4)

NAME:_______________________________

Meridiani Planum Landing Site of Opportunity (MER) Rover

Meridiani Planum interested scientists because it contains an ancient layer of hematite. This hematite was identified using Thermal Emission Spectrometer (TES) data from the Mars Global Surveyor mission. Hematite is an iron oxide that, on Earth, almost always forms in an area containing liquid water. So how did the hematite get there? There were five or six hypotheses to explain this hematite on Mars. For example, the hematite could have been produced directly from iron-rich lavas. This process would not require liquid water. But if water was involved, then the hematite either formed from the iron-rich waters of an ancient lake, or it formed when Martian groundwater bubbled up though layers of volcanic ash. Another idea was to look for minerals such as goethite and magnetite. If goethite were found among the hematite, it would mean that it was formed in watery conditions, but if magnetite were found instead, a watery past was not likely.

On the ground, Opportunity discovered the hematite is in BB-sized spheres, also called "blueberries" by scientists. These loose blueberries are all over the landing site, making what geologists call a lag deposit. It is thought the blueberries formed when strongly acidic groundwater soaked the basaltic sandstone. This sandstone was rich in goethite, another iron-bearing mineral. The water altered the goethite into hematite, forming spherules within the rocks. Then, over time, as the acid-rotted sandstones weathered away, the tougher spherules came free and collected on the surface.



Hematite spheres (blueberries) photographed by Opportunity Rover.
Photo Courtesy of NASA's Jet Propulsion Laboratory

Big Picture Question: Is there evidence for long standing water in Meridiani Planum?

Hypothesis:

____

____

Research Question:

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(C) Student Sheet #2. Identifying the Big Picture Question (1 of 2)

NAME:_______________________________

For this activity, you will need the observations and the topic chosen by your team from the Mars Image Analysis activity. Review the key observations your team used to pick your topic and discuss with your team what was unique and interesting about these observations. Work in a small group to brainstorm some of the big picture questions about your topic. Question prompts have been provided. You are not limited to the number of times you can use a prompt and you might not use all of the prompts. Additional space has been provided in case you want to use a prompt more than once.

What is ____?
(Should be a specific description of an interesting feature you are unable to identify)

How did ____ form?
(Should be a specific feature)

Why does ____ appear __________
____?
(A specific feature and a description of the appearance)

Why is ____ different from ________
____?

(C) Student Sheet #2. Identifying the Big Picture Question (2 of 2)

Now that you have a list of possible big picture questions, share your favorite one or two with the team. Explain why you are interested in answering this question and what observations were made that brought you to the question.

Top 2 Big Picture Questions to share:

#1:

____

____

____

This question is interesting and important because:

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____

____

____

#2:

____

____

____

This question is interesting and important because:

____

____

____

____

(D) Student Sheet #3. Identifying the Explanations (1 of 3)

NAME:_________________________________

As a team, you will now need to debate which Big Picture Question you would like to use. Once your team has selected a Big Picture Question, record it here:

Big Picture Question:

____

____

____

With a big picture question in place, you are ready to start brainstorming possible explanations. Create a list of possible answers or explanations to the Big Picture Question. Work with your small group to create this list.

As you discuss your ideas, they should be **grounded in science**, but can be outside of the box. Just don't go too far outside of the box or it will no longer be grounded in scientific principles.

(D) Student Sheet #3. Identifying the Explanations (2 of 3)

NAME:_______________________________

Take some time with your group to see if there are tools available to test your explanations. An explanation cannot become an hypothesis if you do not have the appropriate tools available to test them. In this case, you can use the *JMARS for MSIP modeling tool* to see what types of data can be collected. Take a few minutes to use the JMARS video tutorials found on the *JMARS for MSIP* tab on the *Mars Education Program* website and record the layers that might be helpful to research of your topic. Record those layers below and explain what type of data they can help you research. An example has been provided for you.

JMARS Layer	What will be measured or recorded?
Ex: Lat/Lon Grid	***Ex: Measure distances of features in km or find the latitude/longitude of a feature***

(D) Student Sheet #3. Identifying the Explanations (3 of 3)

NAME:________________________________

With your understanding of what modeling tools you have available, go back to your original brainstorming list and mark out the explanations you will be unable to research because you do not have the modeling tools available. From the remaining list, choose two explanations you would like to share with the team as a possible explanation.

#1:

____

____

____

#2:

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As a team you will need to debate among all of the possible explanations to determine which is the best. This will be your primary working hypothesis. You may pick a second if it is closely related to the primary. You will revisit this hypothesis after writing your research question to ensure it is testable and falsifiable.

Primary Working Hypothesis (DRAFT):

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____

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(E) Student Sheet #4. Writing a Research Question (1 of 3)

NAME:_______________________________

In order to write a quality research question, you need to consider the information you need to support or refute your explanation (working hypothesis). You will need to consider the variables you intend to collect data on. A variable is something that will be measured or observed in an experiment. Below you will find a list to get you started. This list does not contain all of the possible variables, but has a good amount to get you started. You may have to load *JMARS for MSIP* and start exploring some of the modeling tools available to help you. Create your own list of variables that are specific to your explanation in the area below.

Potential Variables			
Location	**Comparisons**	**Characteristics**	**Measurements**
Region	Similarities	Shape	Length
Distribution	Differences	Type	Diameter
Elevation	Relationships	Texture	Circumference
Lowlands/highlands	Patterns	Quantity	Height

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(E) Student Sheet #4. Writing a Research Question (2 of 3)

NAME:________________________________

Using your list on the previous page, create at least 2 questions for your research on Mars. These questions should be related to your topic/working hypothesis and be testable. Once you have written your questions, use the Evaluation Criteria in the box below to see if your question qualifies as a testable research question. If you can put a check (√) in all of the boxes, your question should be good enough for your team to consider for your research.

Question 1:

____

____

____

Question 2:

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Question		**Evaluation Criteria**
1	2	
		Question can be answered using materials available and in the time allotted.
		Question focuses on specific features that can be observed using the JMARS tool and THEMIS images.
		Question does not focus on ***how*** the feature formed.
		Question includes observations or is similar to one of these: evidence, similarities, differences, relationship, patterns, etc.
		Question is not a ***why*** or ***how come***.

(E) Student Sheet #4. Writing a Research Question (3 of 3)

NAME:________________________________

Share your research questions with your team. As a team, debate which question would be the best potential question for your class to research. Decide which final question is the most interesting and answerable question using THEMIS images.

Try not to feel "possessive" of your own created question. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting question to focus on for your research. The chosen question will most likely change slightly or even greatly throughout the project.

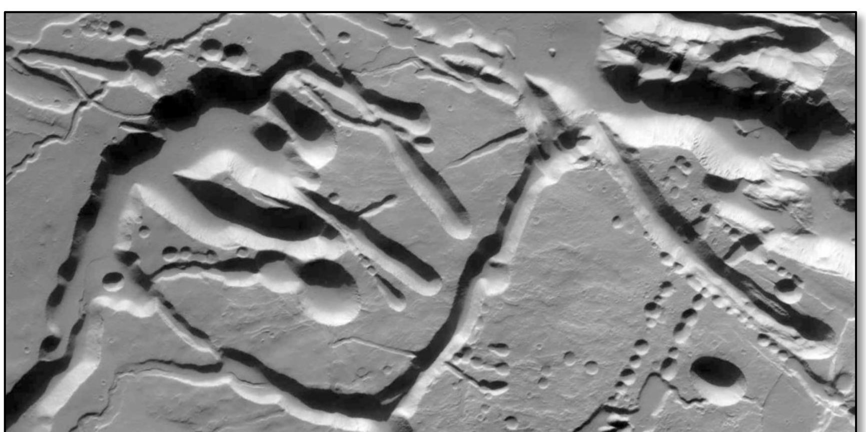
Why is this question the best? List the reasons here:

Final Science Question:

____

____

____



Ascraeus Mons Southwest Flank
NASA/JPL/Arizona State University

(F) Student Sheet #5. Writing a Testable Hypothesis (1 of 2)

NAME:________________________________

Refer to your working hypothesis written in Student Sheet #3 and your newly written team question. You will need to modify the hypothesis to more accurately reflect the research question your team has chosen. Once you have written your hypothesis, use the Evaluation Criteria in the box below to see if your hypothesis qualifies as a testable and falsifiable hypothesis. If you can put a check (√) in all of the boxes, your hypothesis should be good enough for your team to consider for your research.

Working Hypothesis Draft:

____

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Research Question:

____

____

____

Research Hypothesis:

____

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✔	Evaluation Criteria
	Hypothesis can be answered using materials available and in the time allotted.
	Hypothesis focuses on specific features that can be observed using the THEMIS images and JMARS tool.
	Results of the experiment could support the hypothesis OR refute it.
	Hypothesis includes observations or is similar to one of these: evidence, similarities, differences, relationship, patterns, etc.
	Hypothesis could include an 'If…then…" statement, but is not required (*note* not always 100% true. Use if it makes sense.)

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(F) Student Sheet #5. Writing a Testable Hypothesis (2 of 2)

NAME:______________________________

If it meets the criteria, share your hypothesis with your team. As a team, debate which hypothesis would be the best for your class to research. Decide which hypothesis is the most interesting and answerable question using THEMIS images. You may need to make further observations in JMARS for MSIP to help you identify an appropriate hypothesis.

Try not to feel “possessive” of your own created hypothesis. Your creation and participation in the team discussions and decisions will help your team select the best and most interesting hypothesis to focus on for your research.

Why is this hypothesis the best? List the reasons here:

Final Science Question:

____

____

____

Final Research Hypothesis:

____

____

____

(H) Teacher Resource. Questions and Hypotheses Sample Answers (1 of 2)

Below you will find 2 examples of stories from real research on Mars. These examples are stories about how the scientists came up with their questions for research. Read through each of these scenarios looking for the hypothesis and research question. The big picture question has been provided for you. Be prepared to share your findings with the class. Don't forget, sometimes the question may not be written in the form of a question, but more as a statement.

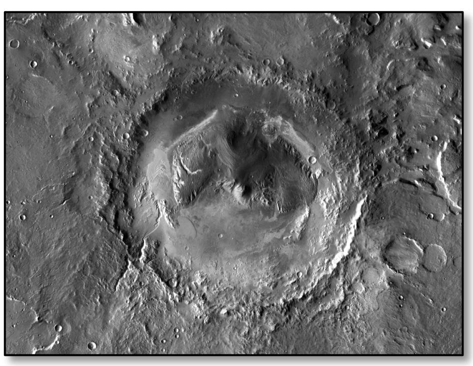
Gale Crater Landing Site of Curiosity (MSL) Rover

Whether life has existed on Mars is an open question that this mission, by itself, is not designed to answer. NASA's Mars Science Laboratory mission will study whether the Gale Crater area of Mars has evidence of past and present habitable environments. Curiosity will look for three conditions that are crucial for habitability; liquid water, a source of energy and other chemical ingredients utilized by life, such as carbon, amino acids, nitrogen, phosphorus, sulfur, and oxygen.

Big Picture Question: Is there evidence of a past or present habitable environment in Gale Crater?

Hypothesis: ***If carbon, amino acids, nitrogen, phosphorus, sulfur, and or oxygen are present in Gale Crater, then there is or may be been a habitable environment.***

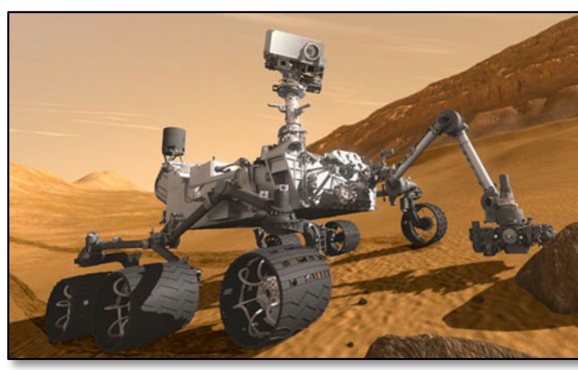
Research Question: ***Is carbon, amino acids, nitrogen, phosphorus, sulfer or oxygen present in Gale Crater?***



Photos Courtesy of NASA's Jet Propulsion Laboratory

Image left: Gale Crater

Image right: Curiosity Rover (MSL)



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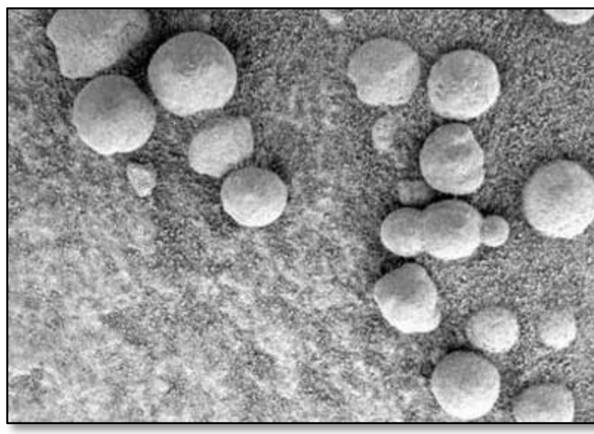
(H) Teacher Resource. Question and Hypotheses Sample Answers (2 of 2)

NAME:______________________________

Meridiani Planum Landing Site of Opportunity (MER) Rover

Meridiani Planum interested scientists because it contains an ancient layer of hematite. This hematite was identified using Thermal Emission Spectrometer (TES) data. Hematite is an iron oxide that, on Earth, almost always forms in an area containing liquid water. So how did the hematite get there? There were five or six hypotheses to explain this hematite on Mars. For example, the hematite could have been produced directly from iron-rich lavas. This process would not require liquid water. But if water was involved, then the hematite either formed from the iron-rich waters of an ancient lake, or it formed when Martian groundwater bubbled up though layers of volcanic ash. Another idea was to look for minerals such as goethite and magnetite. If goethite were found among the hematite, which would mean that it was formed in watery conditions, but if magnetite were found instead, a watery past was not likely.

On the ground, Opportunity discovered the hematite is in BB-sized spheres, also called "blueberries" by scientists. These loose blueberries are all over the landing site, making what geologists call a lag deposit. It is thought the blueberries formed when strongly acidic groundwater soaked the basaltic sandstone. This sandstone was rich in goethite, another iron-bearing mineral. The water altered the goethite into hematite, forming spherules within the rocks. Then, over time, as the acid-rotted sandstones weathered away, the tougher spherules came free and collected on the surface.



Hematite spheres (blueberries) photographed by Opportunity Rover.
Photo Courtesy of NASA's Jet Propulsion Laboratory

Big Picture Question: Is there evidence for long standing water in Meridiani Planum?

Hypothesis: ***If Meridiani Planum had a watery past, then goethite will be found in the area.***

Research Question: ***Is there evidence of goethite (water-rich environment) or magnetite (volcanic rich environment) in Meridiani Planum?***

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(I) Teacher Resource. Evaluation Criteria Rationale

The following table has been developed to explain the rationale behind the evaluation criteria. The rationale may be helpful in your explanations to students regarding high quality research questions.

Evaluation Criteria	Rationale
Question can be answered using materials available an in the time allotted.	Focus on questions that can be answered using an image. Consider the amount of data that will be necessary to answer the question. For example, global (looking at all of Mars) questions are very time consuming and many scientists will spend their careers collecting this kind of data.
Question focuses on specific features that can be found using the THEMIS camera images.	Not all questions can be answered using a picture. If students ask a question that would require video or a direct presence on the planet to observe (such as height of a dust devil), then it is typically not investigable by looking at an image.
Question does not focus on ***how*** the feature formed.	These are often the big picture questions we are trying to answer. We want to know if the processes are the same or different from those we see on Earth, therefore we look for evidence (variables) that then tells us how the feature are formed. A great example of this is "How did Valles Marineris form?" There are many hypotheses as explanations, each it's own research question. See *(B) Student Worksheet. Question and Hypotheses (3 of 4)*
Question includes one of the following words: evidence, similarities, differences, relationships, patterns, etc.	This is a small list, but covers many of the general terms students could use in their question. These are directly related to evidence they could collect. Students will need to plug variables in with these. An example would be "is there evidence that Valles Marineris was formed as a rift valley?"
Question is not a ***why*** or ***how come***?	These are often the big picture questions we are trying to answer. We want to know if the processes are the same or different from those we see on Earth, therefore we look for evidence (variables) that then tell us why we see that feature. These are similar to the questions about how a feature formed.

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(G) Reflection – Science and Engineering Practices (1 of 6)

When scientists study phenomena to better understand how the natural world works or when engineers design solutions to a problem, they engage in certain processes called practices. These practices are, essentially, how science or engineering is done.

These Practices are:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Furthermore, there are 4 understandings about the Nature of Science that scientists have that are a foundation for the practices.

These Understandings about the Nature of Science are:

1. Scientific investigations use a variety of methods.
2. Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).
3. Scientific knowledge is open to revision in light of new evidence.
4. Science models, laws, mechanisms, and theories explain natural phenomena.

(G) Reflection – Crosscutting Concepts (2 of 6)

Some concepts are important to all studies in science and engineering. Seven of these ***Crosscutting Concepts*** – ideas that are important to any science (biology, physics, chemistry, ecology, astronomy, geology, etc.) and to all engineering – have been identified.

i. ***Patterns.*** Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.

ii. ***Cause and effect:*** *Mechanism and explanation*. Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.

iii. ***Scale, proportion, and quantity.*** In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.

iv. ***Systems and system models.*** Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.

v. ***Energy and matter: Flows, cycles, and conservation.*** Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.

vi. ***Structure and function.*** The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.

vii. ***Stability and change.*** For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of a system are critical elements of study.

Furthermore, there are 4 understandings about the Nature of Science that are closely related to the Crosscutting Concepts.

These Understandings about the Nature of Science are:

1. Science is a way of knowing.
2. Scientific knowledge assumes an order and consistency in natural systems.
3. Science is a human endeavor.
4. Science addresses questions about the natural and material world

(F) Reflection – Science and Engineering Practices (3 of 6)

Name: ________________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

a. What Science and/or Engineering Practices did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Practices you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Scientific investigations use a variety of methods.		
Scientific knowledge is based on empirical evidence (knowledge obtained by observation and experimentation).		
Scientific knowledge is open to revision in light of new evidence.		
Science models, laws, mechanisms, and theories explain natural phenomena.		

(F) Reflection – Science and Engineering Practices (4 of 6)

Practice	When?	What is your reasoning?
Asking questions (for science) and defining problems (for engineering)		
Developing and using models		
Planning and carrying out investigations		
Analyzing and interpreting data		
Using mathematics and computational thinking		
Constructing explanations (for science) and designing solutions (for engineering)		
Engaging in argument from evidence		
Obtaining, evaluating, and communicating information		

(F) Reflection – Crosscutting Concepts (5 of 6)

Name: ___________________________________

In your group, reflect carefully on the activities you have just completed and answer the following questions using the table on the next page.

a. What Crosscutting Concepts did you do and which of the understandings about the Nature of Science were important to what you did? (There is probably more than one.)
b. When? During which activities?
c. Explain your reasoning.
d. Be prepared to explain your best thinking about what Crosscutting Concepts you used and when you were doing them in a full class discussion.

Nature of Science	When?	What is your reasoning?
Science is a way of knowing.		
Scientific knowledge assumes an order and consistency in natural systems.		
Science is a human endeavor.		
Science addresses questions about the natural and material world.		

(F) Reflection – Crosscutting Concepts (6 of 6)

Crosscutting Concepts	When?	What is your reasoning?
Patterns		
Cause and effect: Mechanism and explanation		
Scale, proportion, and quantity		
Systems and system models		
Energy and matter: Flows, cycles, and conservation		
Structure and function		
Stability and change		