Mars Image Analysis

Grades: 5-12 Prep Time: ~10 Minutes Lesson Time: 3 Hours


WHAT STUDENTS DO: Establish geologic sequences in a Mars image.

Students step into the shoes of real planetary scientists. Using large-format images of Mars, provided by Mars Education at Arizona State University, students reach conclusions about the geology of Mars. Students are tasked with identifying features on the surface of Mars, determining the surface history of the area, calculating the size of features, and developing investigable questions.

NRC CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT? *NRC Core Question: ESS1: Earth's Place in the Universe*	*Students will be able*
How do people reconstruct and date events in Earth's planetary history? *NRC ESS1.C: The History of the Planet Earth*	**IO1: to reconstruct** geologic events using empirical evidence
Asking Questions and Defining Problems *NRC Practice 1: Science Practices*	

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 About This Activity

The Mars lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and *Teacher Guide* at the end of this document). This taxonomy provides a framework to help organize and align learning objectives, activities, and assessments. The taxonomy has two dimensions. The first dimension, cognitive process, provides categories for classifying lesson objectives along a continuum, at increasingly higher levels of thinking; these verbs allow educators to align their instructional objectives and assessments of learning outcomes to an appropriate level in the framework in order to build and support student cognitive processes. The second dimension, knowledge, allows educators to place objectives along a scale from concrete to abstract. By employing Anderson and Krathwohl's (2001) taxonomy, educators can better understand the construction of instructional objectives and learning outcomes in terms of the types of student knowledge and cognitive processes they intend to support. All activities provide a mapping to this taxonomy in the Teacher Guide (at the end of this lesson), which carries additional educator resources. Combined with the aforementioned taxonomy, the lesson design also draws upon Miller, Linn, and Gronlund's (2009) methods for (a) constructing a general, overarching, instructional objective with specific, supporting, and measurable learning outcomes that help assure the instructional objective is met, and (b) appropriately assessing student performance in the intended learning-outcome areas through rubrics and other measures. Construction of rubrics also draws upon Lanz's (2004) guidance, designed to measure science achievement.

How Students Learn: Science in the Classroom (Donovan & Bransford, 2005) advocates the use of a research-based instructional model for improving students' grasp of central science concepts. Based on conceptual-change theory in science education, the 5E Instructional Model (BSCS, 2006) includes five steps for teaching and learning: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In Explain, students communicate what they have learned, illustrating initial conceptual change. The Elaborate phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the Evaluate stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the Mars instructional series. The 5E stages can be cyclical and iterative.

2.0 Rationale

Students and teachers alike are often confused or mislead by the textbook version of the scientific method. The process of science is often portrayed as a linear process with a defined beginning and endpoint. For many very young students (K-4), the linear process is a good place to start as they are learning the scientific method; however, for older students, the focus on the iterative process of science begins to develop.

The intent of these lessons is to address the misconceptions of the scientific method and teach a much more accurate representation of the process as a whole. Each segment will provide a rationale section, similar to this one, explaining the intent of the lesson along with possible iterations.

As the classroom facilitator, you have been provided options for how far you intend to take your students into the process of science. You have been provided four paths (Figure 1 & 2); each path with increasing quantities of standards that can be covered. You have the option to complete a full research project, or to focus on specific standards you have been struggling to cover.

All four paths start with Mars Image Analysis, which focuses on developing observation skills by distinguishing between everyday and scientific observations. Additionally, students will find that observations occur throughout the research process.

Figure 1. Pathways

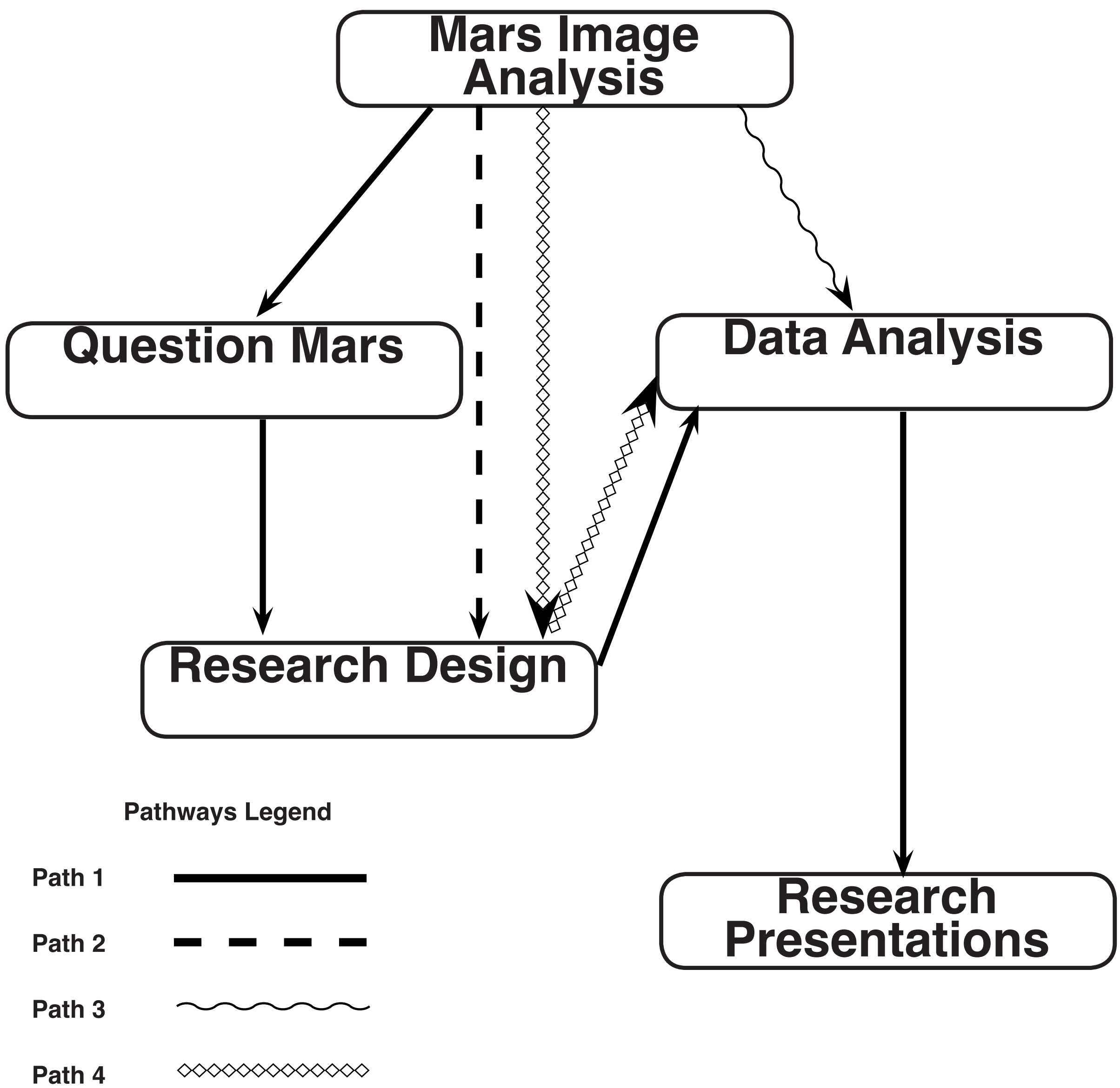


Figure 2. Pathways

Figure 2 - Pathways			
Emphasis	**Lessons in the Path**	**National Standards**	**Est. # of Class periods (45 min segments)**
Path 1: Full scientific process of research	Mars Image Analysis Question Mars Mars Research Design Mars Data Analysis Mars Research Publication	**Science** **Dimension 1: Practices** 1, 2, 3, 4, 5, 6, 7, 8 **Dimension 2: Concept** 1, 2, 3, 4 **Dimension 3: ESS** ESS1C Some types of research: ESS2A, ESS2B, ESS2C, ESS2D	25
Path 2 Developing observation skills and controlled experimental procedures	Mars Image Analysis Mars Research Design	**Science** **Dimension 1: Practices** 2,3 **Dimension 2: Concept** 2, 3, 4 **Dimension 3: ESS** ESS1C	5
Path 3 Developing observation skills, graphing techniques, and graphical interpretation	Mars Image Analysis Mars Data Analysis	**Science** **Dimension 1: Practices** 4, 5, 6 **Dimension 2: Concept** 1, 2, 3, 4 **Dimension 3: ESS** ESS1C	5
Path 4 Developing observation skills, controlled experimental procedures, graphing techniques, and graphical interpretation	Mars Image Analysis Mars Research Design Mars Data Analysis	**Science** **Dimenstion 1: Practices** 2, 3, 4, 5, 6, 7 **Dimension 2: Concept** 1, 2, 3, 4 **Dimension 3: ESS** ESS1C	8

3.0 Materials

Required Materials

Please supply:

- Wet erase marker - 1 per group
- Ruler - 1 per group
- Calculator - 1 per student
- Optional: Computer and Projection System

Materials Supplied from Mars Education:

- Feature ID Charts - 1 per group
- THEMIS image - 1 per group
- MOLA map - 1 per group
- Optional: Mars Image Analysis PowerPoint Presentation

Please Print:

From Student Guide:

(A) What Can You Tell from a Picture? - 1 per group

(B) Background - 1 per student

(C) Lesson Background - 1 per student

(D) Student Data Log - 1 per student

(K) Making Measurements Notes - 1 per student

(L) Student Measurement Data Log - 1 per student

(M) Establishing a Research Topic of Interest - 1 per student

(N) Background Research - 1 per student

(P) Example Observation Table - 1 per student

(Q) Observation Table - 1 per student

(R) Choosing a Topic for Research - 1 per student

From Supplemental Materials:

(E) Sunlight and Shadows - 1 per group

(F) Determining the Relative Ages of Features - 1 per group

(G) Crater Classification – Guide - 1 per group

(H) Relative Age Dating Principles – Guide - 1 per group

(O) Using THEMIS Website to Make Scientific Observations - 1 per student

(S) Feature ID Charts - 1 per group

Optional Materials

Supplemental Materials:

(I) Classifying Craters - 1 per student

(J) Relative Age Dating Principles - 1 per student

(V) Classifying Craters – Sample Answers

(W) Relative Age Dating Principles – Sample Answers

Teacher Guide:

(T) Teacher Resource #1
(U) Teacher Resource #2
(V) Classifying Craters - Sample Answers
(W) Relative Age Dating Principles - Sample Answers
(X) Mars Image Analysis Rubrics
(Y) Alignment of Instructional Objective, Standards, & Learning Outcomes

4.0 Vocabulary

Analyze	consider data and results to look for patterns and to compare possible solutions
Classification	the assignment of objects to categories based on characteristics
Deposition	accumulation of material (such as sediment)
Erosion	the process where the surface of earth is worn away by water, glaciers, winds, waves, etc.
Evaluate	check the scientific validity or soundness
Everyday Observation	the act of noting facts or occurrences that are common characteristics.
Explanations	logical descriptions applying scientific information
Geologic History	the history of geologic events (such as erosion, deposition, glaciers, volcanism, etc.) of an area
Inference	drawing a logical conclusion based on observations and data collection
Scientific Observation	the act of noting facts or occurrences that are unique or interesting and can lead to a scientific research question.
Qualitative Observation	the act of noting facts or occurrences that are based on physical characteristics or attributes, such as color or texture.
Quantitative Observation	the act of noting facts or occurrences that are based on numerical data, such a counting the number of a feature or making measurements of a feature.
Weathering	mechanical and chemical processes that cause exposed rock to decompose

5.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.

- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.

- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see Teacher Guide at the end of this lesson).

Quick View of Standards Alignment:

The Teacher Guide at the end of this lesson provides full details of standards alignment, rubrics, and the way in which instructional objectives, learning outcomes, 5E activity procedures, and assessments were derived through, and align with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view follows:

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

Asking Questions and Defining Problems

NRC Practice 1: Science Practices

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **to reconstruct** geologic events using empirical evidence	**LO1a. to identify geologic features in a THEMIS image** **LO1b. to sequence geologic features using relative dating principles** **LO1c. to explain how the sequence of geologic features were determined**	**NSES: UNIFYING CONCEPTS & PROCESSES:** **K-12: Evidence, models, and explanations** **NSES (D): EARTH AND SPACE SCIENCE:** **Structure of the Earth System** **Grades 5-8:** D1c, D1d **Earth's History** **Grades 5-8:** D2a **The Origin and Evolution of the Earth System** **Grades 9-12:** D3b, D3c **NSES (E): SCIENCE & TECHNOLOGY** **Evaluate Completed Technological Design or Products** **Grades 5-8:** E1d	***Rubrics in Teacher Guide***

This activity also aligns with:

NRC SCIENCE & ENGINEERING PRACTICES

4) Analyzing & interpreting data
5) Using mathematical and computational thinking
6) Constructing explanations and designing solutions

NRC SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

2) Cause and effect
4) Systems and system models

AAAS BENCHMARKS FOR SCIENCE LITERACY

1.A The Scientific World View
1.B Scientific Inquiry
4.A The Universe
4.B The Earth
4.C Processes that Shape the Earth
12.C Manipulation and Observation
12.D Communication Skills
12.E Critical-Response Skills

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS (NCTM)

- Algebra
- Measurement
- Data Analysis and Probability

21ST CENTURY SKILLS

- Critical Thinking and Problem Solving
- Communication
- Collaboration

6.0 Procedure

PREPARATION (~15 minutes)

A. Print materials
B. Organize 1 THEMIS image, 1 MOLA map, 1 set of (S) *Feature ID Charts*, and 1 wet erase marker for each group (face down on table).

STEP 1: ENGAGE (~10 minutes)

What can you tell from a picture?

A. Hand out THEMIS image, (A) *What can you tell from a picture?* sheet

B. Ask students to look at the top image on page 1 of *(A) What can you tell from a picture?*and ask where the arrow is pointing on the map. Ask the students to make observations and share their observations about this area on the image.

C. Next, ask the students to look at the second and third images on (*A) What can you tell from a picture?* (which are zoomed-in versions of this image) in both colorized elevation and black and white infrared imaging. Again, make observations and share them about this area on their image. Do they understand anything different about this area than they did before? Share out with the classroom.

D. Finally, ask the students to look at the final image on (*A) What can you tell from a picture?* - a black and white THEMIS image. This image is further zoomed in for even more detail. One last time, ask them to make observations and share their observations about this area. Do they understand anything different about this area than they did before? Share out with the classroom.

E. At this point, the students should have made many observations. Ask students what information is missing? If we were to attempt to explain why this crater looks so different from other craters, what else would we need to know, observe, or understand to do that? (Students should say they need more observations, find more distinguishing characteristics, possibly a closer image or other types of data.)

F. Point out that images provide the simplest means of exploring another world. We use images of Mars to make observations and identify what other information we need. We zoom in and zoom out to get better detail or more information about our image. We will look at some of these THEMIS images of Mars. Before we do, let's learn a little about THEMIS. Hand out *(B) Background sheet*.

STEP 2: EXPLORE (~60 minutes)

- Print B-L and S in Materials list

Image Analysis

Identify Surface Features

(See Teacher Resource #1 and #2 for an orientation of these materials)

A. Before distributing materials, have students brainstorm analogous features they know exist on Earth that may also exist on Mars. This will help students build knowledge and make connections to previous knowledge throughout the activity.

B. Have students read (*C) Lesson Background* to orient them to the purpose and intent of the lesson.

C. Familiarize and distribute Feature ID Charts, *(E) Sunlight and Shadows Sheet*, and THEMIS images to students.

D. Have students use erasable markers to identify features on laminated THEMIS images using *(S) Feature ID Charts*. Have students initially work with one image.

E. After ~10-15 minutes, have students exchange images they have analyzed so other students can make observations of other images.

   i. End this part of the activity with a discussion of features observed in images from either the PowerPoint slides or paper.

   ii. Ask students to record the identified features into the *(D) Data Log Sheet* and the geologic processes involved in their creation.

Teacher Tip

The observations students will make here are most likely considered "everyday observations." This means they will be simplified to examples such as "There are 30 craters in the image." While this is a true observation, it most likely will not lead to an experimental question. Providing extra time, even when the students appear to be done and off task will allow them to make better observations; however, students may need more content knowledge about the topic they choose before they can make scientific observations. This will be addressed later in the lesson.

<u>Determine the Relative Ages of Features</u>
(See Teacher Resource #2 for an orientation of these materials)

A. Before distributing materials, discuss with students how they may know when one feature is older or younger than another. This will again help students build knowledge and make connections to previous knowledge throughout the activity.

B. Familiarize and distribute *(H) Relative Age Dating Principles Guide* and **(***G) Crater Classification Guide* handout to students.

C. Have students use erasable markers to identify relative ages of features on the original image they were working with. Have students at least label the "oldest" and "youngest" feature. Students can then identify relative ages of other features with respect to the oldest/youngest feature.

D. After ~8-10 minutes, have students discuss the relative ages of features on their image with other groups. Students should discuss the geologic history (what has happened in their area of Mars) as part of their discussion.

E. Ask students to go back to their *(D) Student Data Log* and include the order of which the features have occurred in the Relative Age column and the evidence they used to determine this rank in the Evidence column.

Teacher Tip

Supplemental Materials *(I) Classifying Craters* and *(J) Relative Age Dating Principles* have been provided as additional practice sheets to strengthen their understanding of these principles that are often incorporated in National and State standards. Answer Keys can be found in *(V)* and *(W).*

Calculate the Size of Features

A. Using *(K) Student Measurement Notes* **sheet**, have students measure and simply label features using metric units.

B. Review the example of calculating the size of features in THEMIS images with students.

C. Have students determine the *scale factor* of their image.

D. Once students have determined the *scale factor* of their image, make sure they write this somewhere on their image.

E. Have students use the measurements (in centimeters) of the features labeled on their image and make the appropriate calculation (feature measurement X scale factor) to determine the size of each measured feature in kilometers on Mars.

F. Have students write these measurements for each feature into their *(L) Student Measurement Data Log* in the Measurement column.

Teacher Tip

This would be a good time to discuss scale. Have students estimate the size of the classroom in meters, measure the room, then figure out how many of their classroom would fit into one of their features. For example, in a 3-kilometer wide crater, your classroom may fit inside it 200 times!

STEP 3: EXPLAIN (~20 minutes)

Discussion and Sharing

Identify Surface Features:

A. End this part of the activity with a discussion of features observed in images

Determine the Relative Ages of Features:

A. After ~8-10 minutes, have students discuss the relative ages of features on their image with other groups. Students should discuss the geologic history (what has happened in their area of Mars) as part of their discussion.

Calculate the Size of Features:

A. Have students use the measurements (in centimeters) of the features labeled on their image and make the appropriate calculation (feature measurement X scale factor) to determine the size of each measured feature in kilometers on Mars.

B. Have students write this measurement for each feature into their *(L) Student Measurement Data Log* in the Measurement column.

STEP 4: ELABORATE (~15 minutes)

- Print (M-R)

Compare Mars to Earth

A. Have students take their list of geologic features they have identified on Mars and make a list of similar Earth geologic features and their locations.

B. Compare and contrast the geologic features on both planets.

C. Present a hypothesis as to why the geologic features might differ.

Establishing a Research Topic

Materials Needed:

- (N) Background Research
- (O) Using THEMIS Website to Make Scientific Observations
- (P) Example Observation Table
- (Q) Observation Table (2 sheets)
- Index cards (3”x5”)
- Markers

A. Have each student find a partner and work together to fill in list #1 on the *(M) Establishing a Research Topic of Interest* sheet. They should spend about 3-5 minutes doing this and can come up with topics from any aspect of Mars exploration or geology that interests them.

B. As a class, the students will need to debate and establish their research topic of interest. Should the class be evenly split on a research topic, they could possibly combine their two top topics by establishing a relationship between the two topics to explore.

C. After the students have established a topic, they will need to do some research about it. The goal is to learn how the feature forms, where they are typically found, if there are similar features on Earth or other planetary bodies and how they are the same or different to feature on Earth or other planetary bodies. Students should become experts on their topic. Photocopy as many *(N) Background Research* sheets as they will need.

D. Students may need help getting started with their research. Here are a couple of sources they can use to learn more about their topic of interest:
   - http://themis.asu.edu/topic
   - http://redplanet.asu.edu/

Making Scientific Observations

A. Using background knowledge on their topic, students will make scientific observations about their selected topic as opposed to everyday observations.

B. Point out that the primary difference between these types of observations is the understanding of the topic. A scientist who understands how craters are formed will notice a crater(s) with a different pattern, shape or possibly different features that are not common to the crater. Simply observing that a crater exists is an everyday observation.

C. Their research will help the students make scientific observations. For example, their observations will improve from "There are 30 craters in the image." to "There are 5 Modified craters, 25 destroyed craters, 10 craters are less than 2km wide, 20 are greater than 2 km wide, all of the modified lack a central peak, etc."

D. Students will use *(O) Using THEMIS Website to Make Scientific Observations, (P) Example Observation Table,* and *(Q) Observation Table.*

Choosing a Final Research Topic

A. Students will complete *(R) Choosing a Topic for Research* and share their most interesting scientific observations from *(Q) Observation Table*. These observations will guide the potential discussion and will allow them to group topics or concepts.

B. It may be helpful to use index cards for topics and scientific observations. They may even find they can incorporate a couple of topics of interest for primary and secondary science. Allow the students to debate and come to a consensus on the final topic for research. This is an opportunity to experience authentic science and debate. Scientists typically do not work individually. They discuss ideas and interesting topics for research with other scientists in the field.

> "Critical thinking is required, whether in developing and refining an idea (an explanation or a design) or in conducting an investigation. The dominant activities in this sphere are argumentation and critique, which often lead to further experiments and observations or to changes in proposed models, explanation, or designs. Scientists and engineers use evidence-based argumentation to make the case for their ideas, whether involving new theories or designs, novel ways of collecting data, or interpretations of evidence. They and their peers then attempt to identify weaknesses and limitations in the argument, with the ultimate goal of refining and improving the explanation or design." (National Research Council Science Framework, pg. 46.)

STEP 5: EVALUATE (~20 minutes)

- Print Rubrics

Evaluate proposed solutions using criteria.

Identify Surface Features

A. Ask students to record the identified features into the *(D) Data Log Sheet* and the geologic processes involved in their creation.

Determine the Relative Ages of Features

A. Ask student to go back to their *(D) Student Data Log* and include the order of which the features have occurred in the Relative Age column and the evidence they used to determine this rank in the Evidence column.

Making Scientific Observations and Establishing a Research Topic

A. For students to make scientific observations instead of everyday observations, they will need to understand a topic very well. To do that, they will need to establish a topic that interests them about Mars and do in-depth research on that topic. Scientific observations lead to testable research questions. A rubric has been provided to evaluate the student's ability to write scientific observations and to actively debate the qualities of a good research topic.

7.0 Extensions

CALCULATING HEIGHTS AND DEPTHS OF FEATURES:
Students can calculate depths and heights of features by dividing the length of a shadow by the tangent of the incidence angle (incidence angle information is provided).

To do this, students would use the following steps:
- Measure the width of the shadow in centimeters.
- Using the calculated scale factor (Part 3 of the *Mars Image Analysis* activity), convert the shadow measurement to kilometers.
- Divide that calculated measurement by the tangent of the incidence angle to compute the depth of the feature being observed.

PARTICIPATING IN THE MARS STUDENT IMAGING PROJECT:
This activity can be used as an introduction to participation in the Mars Student Imaging Project (MSIP). The Mars Student Imaging Project allows students to conduct authentic research about Mars with the opportunity to target a new image from the THEMIS visible camera onboard the Mars Odyssey spacecraft. For more information on the Mars Student Imaging Project, go to http://marsed.asu.edu/msip-home.

ANALYZING OTHER THEMIS IMAGES:
Students can analyze other THEMIS visible images available on the THEMIS website: http://themis.asu.edu.

GETTING INVOLVED IN OTHER MARS-RELATED OPPORTUNITIES:
Students can get involved in activities available on NASA's Be A Martian website: http://beamartian.jpl.nasa.gov/welcome.

8.0 Evaluation/Assessment

Use the *(W) Mars Image Analysis Rubric* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The rubric aligns with the NRC Framework, National Science Education Standards, and the instructional objective(s) and learning outcomes in this lesson.

9.0 References

Anderson, L.W., & Krathwohl (Eds.). (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives.* New York: Longman.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carson Powell, J., Westbrook, A., Landes, N. (2006) *The BSCS 5E instructional model: origins, effectiveness, and applications.* Colorado Springs: BSCS.

Donovan, S. & Bransford, J. D. (2005). *How Students Learn: History, Mathematics, and Science in the Classroom.* Washington, DC: The National Academies Press.

Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12.* Thousand Oaks: Corwin Press.

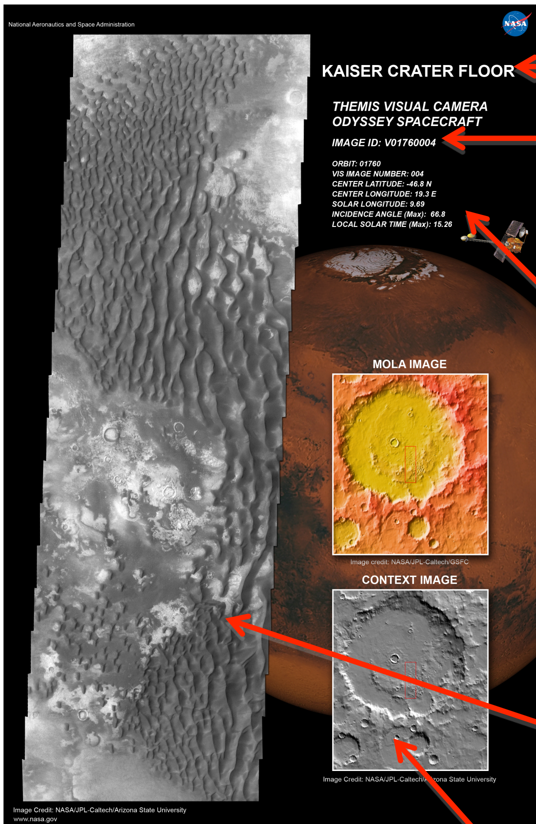
Miller, Linn, & Gronlund. (2009). *Measurement and assessment in teaching*. Upper Saddle River, NJ: Pearson.

National Academies Press. (1996, January 1). *National science education standards*. Retrieved February 7, 2011 from http://www.nap.edu/catalog.php?record_id=4962

National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas.* Committee on a Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org/

(T) Teacher Resource #1 (1 of 2)



THEMIS visible images are ~18 km wide.

Title: Names the general region where the image is located on Mars.

Image ID: Includes the orbit # in which the image was taken (first 5 digits) followed by a 3 digit number that indicates the count of the visible images that were taken during that orbit.

***Center Latitude and Center Longitude*:** Exact location of this image on a map of Mars.

Incidence Angle: Angle of the Sun when the image was taken. This would be used if the students wanted to measure depth or heights of features using the sun or incidence angle.

Orbit: Orbit in which the image was acquired.

Mars Solar Time: Time (on Mars) when the image was taken.

THEMIS Image: The long, rectangular image consisting of 18-19 framelets. Framelets are angled due to the rotation of the planet beneath the camera as it takes photos.

Context Image: Shows the surrounding area where the THEMIS image was taken. The THEMIS image "stamp" is the rectangular box in the center of the context image.

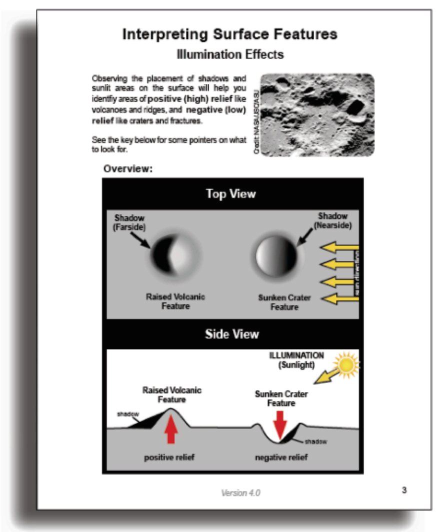
NOTE: With THEMIS visible images, the sunlight is coming from the left. A feature with a shadow on the left is carved into the surface. (Example: an impact crater will have the shadow on the left.)

(T) Teacher Resource #1 (2 of 2)

Additional Details:

- **Image ID #:** Allows you to view this image on the THEMIS viewer website (http://viewer.mars.asu.edu/#start)
- **Mars Solar Time:** Time is based on a 24-hour clock and uses percentages of hours rather than minutes. For example, if an image was taken at 15.75, it would be 3pm and 75% of an hour, or 3:45pm. If an image was taken at 16.2, the time would be 4pm and 20% of an hour or 4:12pm.
- **Context Image:** Shows a Mars Orbiter Laser Altimeter (MOLA) shaded relief map. This is not a photograph but is considered an "artificial image" that uses data acquired by the MOLA instrument to provide a black and white context showing elevation differences.

SUNLIGHT AND SHADOWS

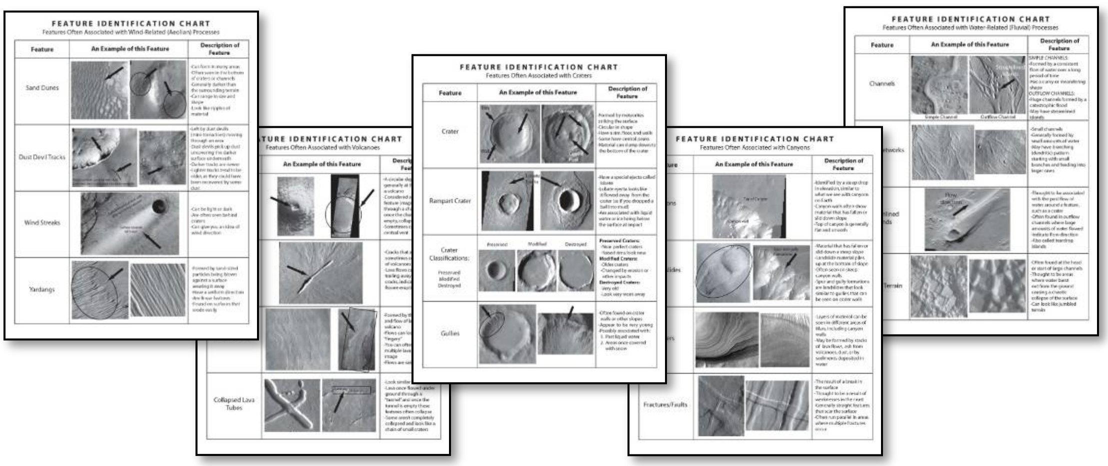


The Sunlight and Shadows sheet will help students to identify features in their LROC WAC Mosaic by orienting them to how shadowing is used to identify a raised or carved feature. Some students may need additional practice with this concept using concrete materials such as a cup and flashlight. Have students discover how the lighting works with the cup turned right-side up and up-side down.

(U) Teacher Resource #2

FEATURE IDENTIFICATION CHARTS

marsed.asu.edu/files/msip_resources/FeatureIDCharts.pdf

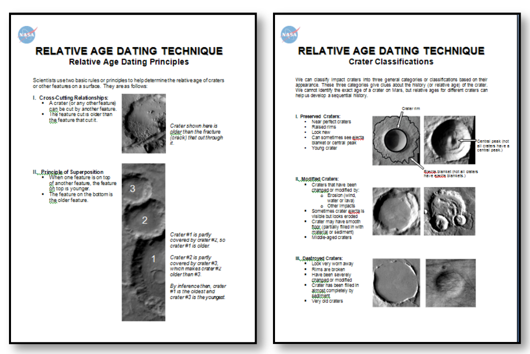


The Feature ID Charts will help students learn the names of different geologic features on Mars. They also provide information on how features form. The information at the top of each chart indicates what geologic process the listed features are associated with. There are 5 total charts that focus on features associated with *canyons*, *craters*, *wind*, *water*, and *volcanoes*. There are many other features students may observe in images that are not included on these charts. Encourage students to share other features they may know.

RELATIVE AGE DATING TECHNIQUE HANDOUTS

marsed.asu.edu/files/msip_resources/RelativeAgeDatingTechniqueHandout.pdf

One additional tool students will use for this activity are the **Relative Age Dating Technique** handouts. These two pages will help students identify what features are older or younger, which will help them better understand the geologic history of the surface.



(X) Teacher Resource. Mars Image Analysis Rubric (1 of 4)

You will know the level to which your students have achieved the **Learning Outcomes**, and thus the **Instructional Objective(s)**, by using the suggested **Rubrics** below.

Instructional Objective 1: to reconstruct geologic events using empirical evidence

Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

National Science Education Standards (NSES)
(A) Science as Inquiry: Understandings about Scientific Inquiry
Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models (Grades 5-8: A2a).

National Science Education Standards (NSES)
(D) Earth and Space Science: Structure of the Earth System

Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and depositions of sediment, while destructive forces include weathering and erosion (Grades 5-8: D1c).

(X) Teacher Resource. Mars Image Analysis Rubric (2 of 4)

Some changes in the solid earth can be describes as the "rock cycle." Old rocks at the Earth's surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues (Grades 5-8: D1d).

National Science Education Standards (NSES)
(D) Earth and Space Science: Earth's History
The earth process we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet (Grades 5-8: D2a).

National Science Education Standards (NSES)
(D) Earth and Space Science: The Origin and Evolution of the Earth System
Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed (Grades 9-12: D3b).
Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years (Grades 9-12: D3c).

National Science Education Standards (NSES)
(E) Science and Technology: Abilities of Technological Design
Evaluate a Product or Design. Students should use criteria relevant to the original purpose or need, consider a variety of factors that might affect acceptability and suitability for intended users or beneficiaries, and develop measures of quality with respect to such criteria and factors; they should also suggest improvements and, for their own products, try proposed modifications. (Grades 5-8: E1d)

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a. to identify geologic features in a THEMIS image	Geologic features identifications are logical and supported by evidenced	Geologic features are logical and somewhat supported by evidence	Geologic features are reasonably logical and somewhat supported by evidence	Geologic features are illogical and/or not supported by evidence

(X) Teacher Resource. Mars Image Analysis Rubric (3 of 4)

Related Standards (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to Do Scientific Inquiry
Identify questions that can be answered through scientific investigations (Grades 5-8: A1a).
Think critically and logically to make the relationship between evidence and explanations (Grades 5-8: A1e).

Identify questions and concepts that guide scientific investigation (Grades 9-12: A1a)
Formulate and revise scientific explanations and models using logic and evidence (Grades 9-12: A1d)

National Science Education Standards (NSES)
(A) Science as Inquiry: Understandings about Scientific Inquiry
Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models (Grades 5-8: A2a).

Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1b: to sequence geologic features using relative dating principles	Geologic sequences are logical and supported by evidenced	Geologic sequences are logical and somewhat supported by evidence	Geologic sequences are reasonably logical and somewhat supported by evidence	Geologic sequences are illogical and/or not supported by evidence

(X) Teacher Resource. Mars Image Analysis Rubric (4 of 4)

National Science Education Standards (NSES)
(A) Science as Inquiry: Abilities Necessary to Do Scientific Inquiry
Think critically and logically to make the relationship between evidence and explanations (Grades 5-8: A1e).
Formulate and revise scientific explanations and models using logic and evidence (Grades 9-12: A1d).

National Science Education Standards (NSES)
(A) Science as Inquiry: Understandings about Scientific Inquiry
Different kinds of questions suggest different kinds of scientific investigations. Some investigations involve observing and describing objects, organisms, or events; some involve collecting specimens; some involve experiments; some involve seeking more information; some involve discovery of new objects and phenomena; and some involve making models (Grades 5-8: A2a).

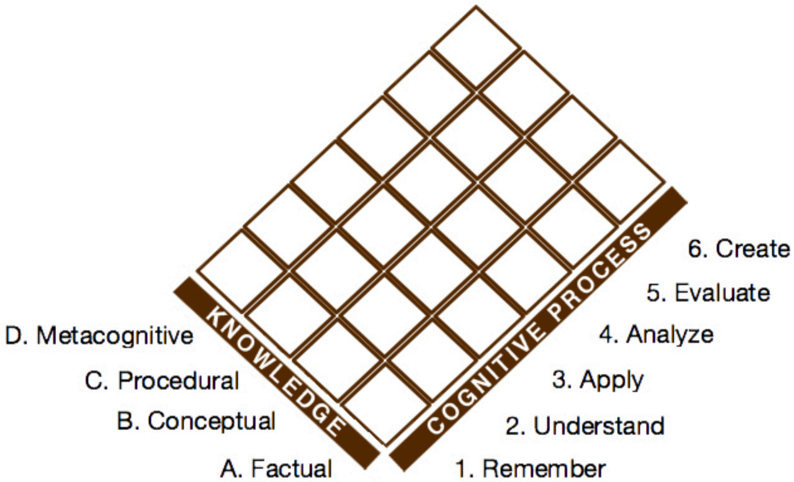
National Science Education Standards (NSES)
(D) Earth and Space Science: Structure of the Earth System
Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and depositions of sediment, while destructive forces include weathering and erosion (Grades 5-8: D1c).
Some changes in the solid earth can be describes as the "rock cycle." Old rocks at the Earth's surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues (Grades 5-8: D1d).

National Science Education Standards (NSES)
(D) Earth and Space Science: Earth's History
The earth process we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet (Grades 5-8: D2a).

National Science Education Standards (NSES)
(D) Earth and Space Science: The Origin and Evolution of the Earth System
Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed (Grades 9-12: D3b).
Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years (Grades 9-12: D3c).

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1c to explain how the sequence of geologic features were determined	Geologic sequences are logical and supported by evidenced	Geologic sequences are logical and somewhat supported by evidence	Geologic sequences are reasonably logical and somewhat supported by evidence	Geologic sequences are illogical and/or not supported by evidence

(Y) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (1 of 3)



This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). Activity procedures and assessments are designed to support the target knowledge/cognitive process.

Knowledge	Cognitive Process
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. Procedural** **Ca:** Knowledge of subject-specific skills and algorithms **Cb:** Knowledge of subject-specific techniques and methods **Cc:** Knowledge of criteria for determining when to use appropriate procedures **D. Metacognitive** **Da:** Strategic Knowledge **Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge **Dc:** Self-knowledge	**1. Remember** **1.1** Recognizing (Identifying) **1.2** Recalling (Retrieving) **2. Understand** **2.1** Interpreting (Clarifying, Paraphrasing, Representing, Translating) **2.2** Exemplifying (Illustrating, Instantiating) **2.3** Classifying (Categorizing, Subsuming) **2.4** Summarizing (Abstracting, Generalizing) **2.5** Inferring (Concluding, Extrapolating, Interpolating, Predicting) **2.6** Comparing (Contrasting, Mapping, Matching **2.7** Explaining (Constructing models) **3. Apply** **3.1** Executing (Carrying out) **3.2** Implementing (Using) **4. Analyze** **4.1** Differentiating (Discriminating, distinguishing, focusing, selecting) **4.2** Organizing (Finding coherence, integrating, outlining, parsing, structuring) **4.3** Attributing (Deconstructing) **5. Evaluate** **5.1** Checking (Coordinating, Detecting, Monitoring, Testing) **5.2** Critiquing (Judging) **6. Create** **6.1** Generating (Hypothesizing) **6.2** Planning (Designing) **6.3** Producing (Constructing)

(Y) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

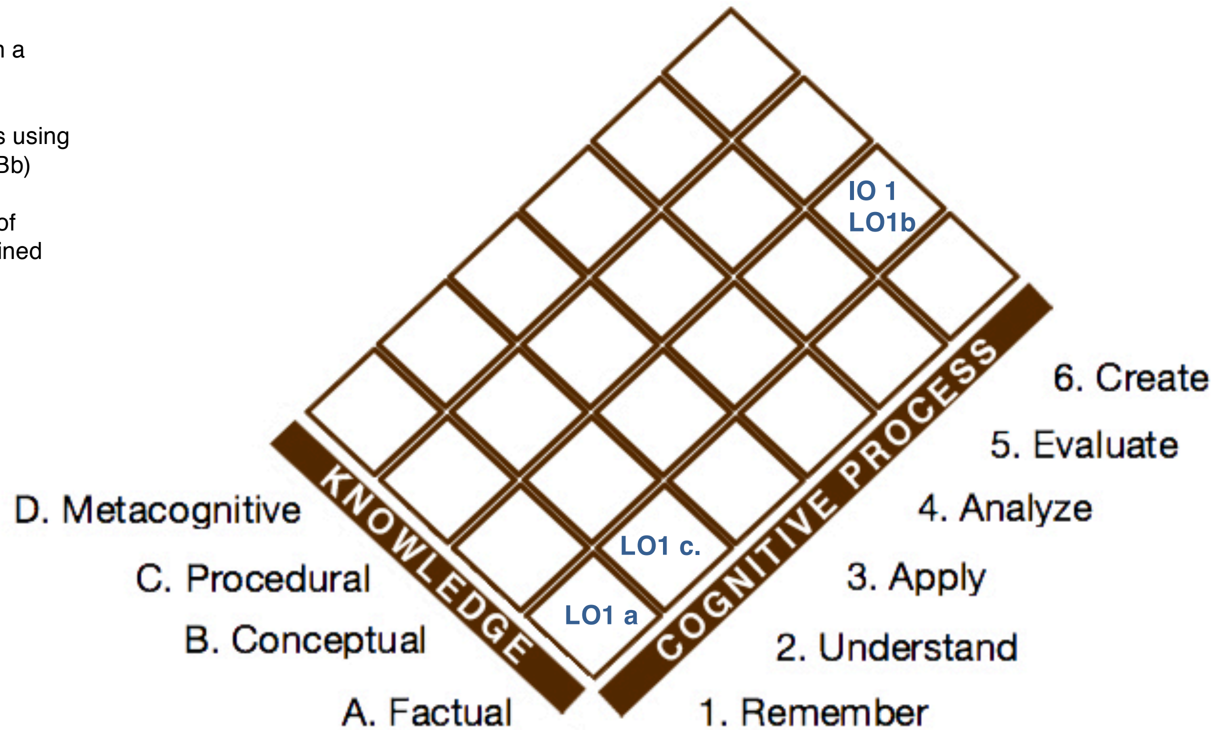
The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Pedagogically, it is important to ensure that objectives and outcomes are written to match the knowledge and cognitive process students are intended to acquire.

IO1: to reconstruct geologic events using empirical evidence (6.3; Bb)

LO1a. to identify geologic features in a THEMIS image (1.1; Ab)

LO1b. to sequence geologic features using relative dating principles (6.3; Bb)

LO1c. to explain how the sequence of geologic features were determined (2.7; Ab)



(Y) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (3 of 3)

The design of this activity leverages Anderson & Krathwohl's (2001) taxonomy as a framework. Below are the knowledge and cognitive process types students are intended to acquire per the instructional objective(s) and learning outcomes written for this lesson. The specific, scaffolded 5E steps in this lesson (see 5.0 Procedures) and the formative assessments (worksheets in the Student Guide and rubrics in the Teacher Guide) are written to support those objective(s) and learning outcomes. Refer to (X, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (X, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: **to reconstruct** geologic events
- 6.3: to produce
- Bb: principles and generalizations

To meet that instructional objective, students will demonstrate the abilities:

LO1a: **to identify** geologic features in a THEMIS image
- 1.1: to identify
- Ab: specific details and elements

LO1b: **to sequence** geologic features using relative dating principles
- 6.3: to construct
- Bb: principles and generalizations

LO1c: **to explain** how the sequence of geologic features were determined
- 2.7: to explain
- Ab: specific details and elements