Mars – The Xtreme-o-philes

High School NGSS, Common Core, and 21st Century Skills Alignment Document

WHAT STUDENTS DO: Conduct an investigation and construct explanations for the viability of extremophiles in specific Mars environments

In this lesson, students will use research to learn about the similarities and differences between Earth and Mars environments along with the different types of extremophiles that can be found on Earth. The class will continue their exploration through a matching activity to determine which extremophiles could potentially exist in specific environments on Mars because of their unique form of obtaining energy from their environments. Students will:

- Summarize information about Earth and Mars along with types of extremophiles;
- Recognize the difference between living and non-living objects;
- Infer the potential for life in extreme environments on Mars; and
- Explain which regions of Mars are the most likely candidates to find these extremophiles.

NGSS CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
HOW CAN THERE BE SO MANY SIMILARITIES AMONG ORGANISMS YET SO MANY DIFFERENT KINDS OF PLANTS, ANIMALS, AND MICROORGANISMS? *NGSS Core Question: LS4: Biological Evolution: Unity and Diversity* **HOW AND WHY DO ORGANISMS INTERACT WITH THEIR ENVIRONMENT AND WHAT ARE THE EFFECTS OF THESE INTERACTIONS?** *NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics* **How does the environment influence populations of organisms over multiple generations?** *NGSS LS4.C: Adaptation* **How do organisms interact with the living and nonliving environments to obtain matter and energy?** *NGSS LS2.A: Interdependent Relationships in Ecosystems*	*Students will be able* **IO1:** **to construct** explanations for how genetic variations of traits in a population increase some individual's probability of surviving and reproducing in a specific environment, which tends to increase these traits and suppress other traits in the population. **IO2:** **Use the systems' model** that organisms and populations of organisms are dependent on their environmental interactions with nonliving (abiotic) factors in Earth ecosystems to predict the presence of organisms in martian environments and defend your prediction with data.

1.0 About This Activity

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.

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. The 5E stages can be cyclical and iterative.

2.0 Instructional Objectives, Learning Outcomes, & Standards

Instructional objectives and learning outcomes are aligned with

- National Research Council's, *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*
- Achieve Inc.'s, *Next Generation Science Standards (NGSS)*
- National Governors Association Center for Best Practices (NGA Center) and Council of Chief State School Officers (CCSSO)'s, *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and* Technical Subjects
- Partnership for 21st Century Skills, *A Framework for 21st Century Learning*

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

- Your **instructional objectives (IO)** for this lesson align with the NGSS Framework and NGSS.
- 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:

HOW CAN THERE BE SO MANY SIMILARITIES AMONG ORGANISMS YET SO MANY DIFFERENT KINDS OF PLANTS, ANIMALS, AND MICROORGANISMS?

NGSS Core Question: LS4: Biological Evolution: Unity and Diversity

HOW AND WHY DO ORGANISMS INTERACT WITH THEIR ENVIRONMENT AND WHAT ARE THE EFFECTS OF THESE INTERACTIONS?

NGSS Core Question: LS2: Ecosystems: Interactions, Energy, and Dynamics

How does the environment influence populations of organisms over multiple generations?

NGSS LS4.C: Adaptation

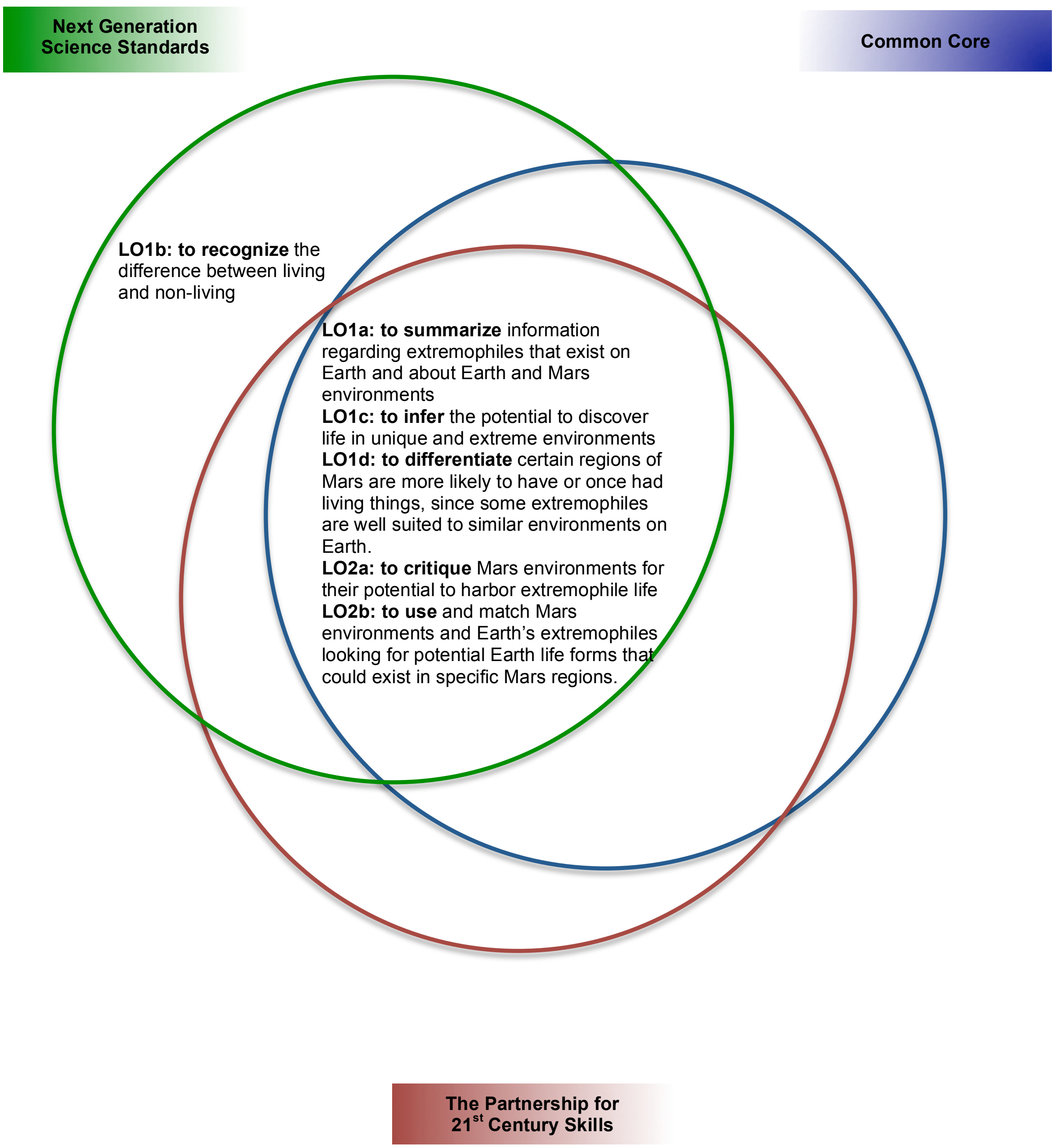
How do organisms interact with the living and nonliving environments to obtain matter and energy?

NGSS LS2.A: Interdependent Relationships in Ecosystems

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*
IO1: **to construct** an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. **IO2:** **Use the systems' model** that organisms and populations of organisms are dependent on their environmental interactions with nonliving (abiotic) factors in Earth ecosystems to predict the presence of organisms in martian environments and defend your prediction with data.	**LO1a. to summarize** information regarding extremophiles that exist on Earth and about Earth and Mars environments **LO1b. to recognize** the difference between living and non-living **LO1c. to infer** the potential to discover life in unique and extreme environments **LO1d. to differentiate** certain regions of Mars are more likely to have or once had living things, since some extremophiles are well suited to similar environments on Earth. **LO2a. to critique** Mars environments for their potential to harbor extremophile life **LO2b. to use and match** Mars environments and Earth's extremophiles looking for potential Earth life forms that could exist in specific Mars regions.	**NGSS Disciplinary Core Idea:** **LS4.B: Natural Selection** **LS2.A: Interdependent Relationships in Ecosystems** **NGSS Practices:** **Constructing Explanations and Designing Solutions** **Developing and Using Models** **Engaging in Argument from Evidence** **NGSS Cross-Cutting Concept:** **Patterns** **Cause and Effect** **Systems and System Models** **NGSS Connections to Nature of Science:** **Scientific Knowledge Assumes an Order and Consistency in Natural Systems** **Scientific Knowledge is Based on Empirical Evidence**

3.0 Learning Outcomes, NGSS, Common Core, & 21st Century Skills Connections

The connections diagram is used to organize the learning outcomes addressed in the lesson to establish where each will meet the Next Generation Science Standards, ELA Common Core Standards, and the 21st Century Skills and visually determine where there are overlaps in these documents.



4.0 Evaluation/Assessment

Rubric*:* A rubric has been provided to assess student understanding of the simulation and to assess metacognition. A copy has been provided in the Student Guide for students to reference prior to the simulation. This rubric will allow them to understand the expectations set before them.

5.0 References

Achieve, Inc. (2013). *Next generation science standards*. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

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.

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 Governors Association Center for Best Practices & Council of Chief State School Officers. (2010). *Common Core State Standards*. Washington, DC: Authors.

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

(L) Teacher Resource. Mars – The Xtreme-o-philes Rubric (1 of 3)

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 construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment

Instructional Objective 2: Use the systems' model that organisms and populations of organisms are dependent on their environmental interactions with nonliving (abiotic) factors in Earth ecosystems to predict the presence of organisms in martian environments and defend your prediction with data.

Related Standard(s)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below:
(HS-LS2-1),(HS-LS2-2), (HS-LS4-2), (HS-LS4-3), (HS-LS4-4), (HS-LS4-5), (HS-LS4-6)

Next Generation Science Standards (NGSS)
Practices: Constructing Explanations and Designing Solutions
(Learning Outcomes Addressed: LO1a, LO2a)

- Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students' own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future.

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.

Next Generation Science Standards (NGSS)
Practices: Developing and Using Models
(Learning Outcomes Addressed: LO2a, LO2b)

- Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system.

Next Generation Science Standards (NGSS)
Practices: Engaging in Argument from Evidence
(Learning Outcomes Addressed: LO1c, LO2a, LO2b)

- Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues.

- Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments.

- Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence, challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining additional information required to resolve contradictions.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Patterns
(Learning Outcomes Addressed: LO1b, LO1c, LO1d, LO2a, LO2b)

- Students observe patterns in systems at different scales and cite patterns as empirical evidence for causality in supporting their explanations of phenomena. They recognize classifications or explanations used at one scale may not be useful or need revision using a different scale; thus requiring improved investigations and experiments.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Cause and Effect
(Learning Outcomes Addressed: LO1b, LO1c, LO1d, LO2a, LO2b)

- Students understand that empirical evidence is required to differentiate between cause and correlation and to make claims about specific causes and effects. They suggest cause and effect relationships to explain and predict behaviors in complex natural and designed systems. They also propose causal relationships by examining what is known about smaller scale mechanisms within the system. They recognize changes in systems may have various causes that may not have equal effects.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Systems and System Models
(Learning Outcomes Addressed: LO1b, LO1c, LO1d, LO2a, LO2b)

- They can also use models and simulations to predict the behavior of a system, and recognize that these predictions have limited precision and reliability due to the assumptions and approximations inherent in the models.

Next Generation Science Standards (NGSS)
Connections to the Nature of Science: Scientific Knowledge Assumes an Order and Consistency in Natural Systems
(Learning Outcomes Addressed: LO1c, LO1d, LO2a, LO2b)

- Scientific knowledge is based on the assumption that natural laws operate today as they did in the past and they will continue to do so in the future.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: LS2.A: Interdependent Relationships in Ecosystems (Learning Outcomes Addressed: LO1c, LO1d, LO2a, LO2b)

- Ecosystems have carrying capacities, which are limits to the numbers of organisms and populations they can support. These limits result from such factors as the availability of living and nonliving resources and from such challenges such as predation, competition, and disease. Organisms would have the capacity to produce populations of great size were it not for the fact that environments and resources are finite. This fundamental tension affects the abundance (number of individuals) of species in any given ecosystem.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: LS4.C: Adaptation
(Learning Outcomes Addressed: LO1c, LO1d, LO2a, LO2b)

- Evolution is a consequence of the interaction of four factors: (1) the potential for a species to increase in number, (2) the genetic variation of individuals in a species due to mutation and sexual reproduction, (3) competition for an environment's limited supply of the resources that individuals need in order to survive and reproduce, and (4) the ensuing proliferation of those organisms that are better able to survive and reproduce in that environment.

- Natural selection leads to adaptation, that is, to a population dominated by organisms that are anatomically, behaviorally, and physiologically well suited to survive and reproduce in a specific environment. That is, the differential survival and reproduction of organisms in a population that have an advantageous heritable trait leads to an increase in the proportion of individuals in future generations that have the trait and to a decrease in the proportion of individuals that do not.

- Adaptation also means that the distribution of traits in a population can change when conditions change.

- Changes in the physical environment, whether naturally occurring or human induced, have thus contributed to the expansion of some species, the emergence of new distinct species as populations diverge under different conditions, and the decline–and sometimes the extinction–of some species.

- Species become extinct because they can no longer survive and reproduce in their altered environment. If members cannot adjust to change that is too fast or drastic, the opportunity for the species' evolution is lost.

Common Core State Standards
Reading for Literacy in Science and Technical Subjects Standards 9-12: Key Ideas and Details
(Learning Outcomes Addressed: LO1a)

- Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions. (Grade 9-10)
- Determine the central ideas or conclusions of a text; trace the text's explanation or depiction of a complex process, phenomenon, or concept; provide an accurate summary of the text. (Grade 9-10)

- Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account. (Grade 11-12)
- Determine the central ideas or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. (Grade 11-12)

Common Core State Standards
Reading for Literacy in Science and Technical Subjects Standards 9-12: Craft and Structure
(Learning Outcomes Addressed: LO2b)

- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 9–10 texts and topics. (Grade 9-10)
- Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11–12 texts and topics. (Grade 11-12)

Common Core State Standards
Writing for Literacy in Science and Technical Subjects Standards 9-12: Text Types and Purposes
(Learning Outcomes Addressed: LO1a, LO2a)

- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Grade 9-10)
    - Introduce a topic and organize ideas, concepts, and information to make important connections and distinctions; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
    - Develop the topic with well-chosen, relevant, and sufficient facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
    - Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.
    - Use precise language and domain-specific vocabulary to manage the complexity of the topic and convey a style appropriate to the discipline and context as well as to the expertise of likely readers.
    - Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
    - Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade 9-10)
- Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation. (Grade 9-10)

- Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Grade 11-12)
    - Introduce a topic and organize complex ideas, concepts, and information so that each new element builds on that which precedes it to create a unified whole; include formatting (e.g., headings), graphics (e.g., figures, tables), and multimedia when useful to aiding comprehension.
    - Develop the topic thoroughly by selecting the most significant and relevant facts, extended definitions, concrete details, quotations, or other information and examples appropriate to the audience's knowledge of the topic.
    - Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among complex ideas and concepts.
    - Use precise language, domain-specific vocabulary and techniques such as metaphor, simile, and analogy to manage the complexity of the topic;

    convey a knowledgeable stance in a style that responds to the discipline and context as well as to the expertise of likely readers.
  - Provide a concluding statement or section that follows from and supports the information or explanation provided (e.g., articulating implications or the significance of the topic).
- Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience. (Grade 11-12)
- Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. (Grade 11-12)

21st Century Skills
Collaboration
(Learning Outcomes Addressed: LO1a, LO1c, LO1d, LO2b)

- Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling. (Grade 12 Benchmark)

(L) Teacher Resource. Mars – The Xtreme-o-philes Rubric (1 of 3)

Learning Outcomes Assessment:

	Expert	Proficient	Intermediate	Beginner
LO1a: to summarize information regarding extremophiles that exist on Earth and about Earth and Mars environments	Table information is accurate and complete. Presentation of summary articulates information accurately and completely and incorporates images as examples.	Table information is complete and accurate. Presentation communicates most information completely and accurately. May or may not have images as examples.	Table information is completed. Presentation communicates some information accurately. May or may not have images as examples.	Table information is completed. Presentation communicates information.
LO1b: to recognize the difference between living and non-living	All matches are between an abiotic and biotic. Many examples of materials provided from the nonliving environment that are used to support the living organism are accurate.	All matches are between an abiotic and biotic. At least one example of a material from the nonliving environment that is used to support a living organism is included and accurate.	All or most matches are between abiotic and biotic. At least one example of a material from the nonliving environment is used to support a living organism is included.	Most matches are between abiotic and biotic. Biotic example may be provided of materials used to support a living organism.
LO1c: to infer the potential to discover life in unique and extreme environments	A wide variety of descriptions connecting the unique environments on Mars and even more unique extremophiles found on Earth as examples of the potential to find life in extreme and unique environments.	A variety of descriptions connecting the unique environments on Mars and even more unique extremophiles found on Earth as examples of the potential to find life in extreme and unique environments.	A description connecting the unique environments on Mars and even more unique extremophiles found on Earth as examples of the potential to find life in extreme and unique environments.	A wide variety of descriptions of extremophiles found on Earth and the environments they are found within.
LO1d: to differentiate certain regions of Mars are more likely to have or once had living things, since some extremophiles are well suited to similar environments on Earth.	A landing site or two are selected on Mars and fully justified in explanations of why these regions could potentially harbor specific types of extremophiles similar to those found on Earth. Addresses and explains the potential of past extremophile life. Clearly articulates life has not been found on Mars to date.	A landing site is selected on Mars and well justified in explanations of why this region could potentially harbor specific types of extremophiles similar to those found on Earth. Addresses the potential of past extremophile life. Clearly articulates life has not been found on Mars.	A landing site is selected on Mars and includes an explanation of why this region could potentially harbor specific types of extremophiles similar to those found on Earth. Might discuss the misconception of confirmed presence of life on Mars.	A landing site is selected on Mars and lists specific types of extremophiles that could potentially be similar to those found on Earth. May discuss the misconception of confirmed presence of life on Mars.

LO2a: to critique Mars environments for their potential to harbor extremophile life	A landing site or two are selected on Mars and fully justified in explanations of why these regions could potentially harbor specific types of extremophiles similar to those found on Earth. Addresses and explains the potential of past extremophile life. Clearly articulates life has not been found on Mars to date.	A landing site is selected on Mars and well justified in explanations of why this region could potentially harbor specific types of extremophiles similar to those found on Earth. Addresses the potential of past extremophile life. Clearly articulates life has not been found on Mars.	A landing site is selected on Mars and includes an explanation of why this region could potentially harbor specific types of extremophiles similar to those found on Earth. Might discuss the misconception of confirmed presence of life on Mars.	A landing site is selected on Mars and lists specific types of extremophiles that could potentially be similar to those found on Earth. May discuss the misconception of confirmed presence of life on Mars.
LO2b: to use and match Mars environments and Earth's extremophiles looking for potential Earth life forms that could exist in specific Mars regions	Mars environments and extremophile matches are logical and fully justified and demonstrate the use of all extremophile preferences and environmental conditions. Multiple matches are made to many environments and addresses the wide variety of potential regions extremophiles could exist.	Mars environments and extremophile matches are logical and justified and demonstrate the use of most extremophile preferences and environmental conditions. Most matches are made to many environments and addresses the wide variety of potential regions extremophiles could exist.	Mars environments and extremophile matches are justified and demonstrate the use of most extremophile preferences and environmental conditions. A couple of matches are made to many environments and addresses the potential regions the extremophile could exist.	Mars environments and extremophile matches are made and use one or two extremophile preferences and environmental conditions. Most matches are made to only 1 environment.

(L) Teacher Resource. Mars – The Xtreme-o-philes Rubric (2 of 3)

Partnership for 21st Century Skills

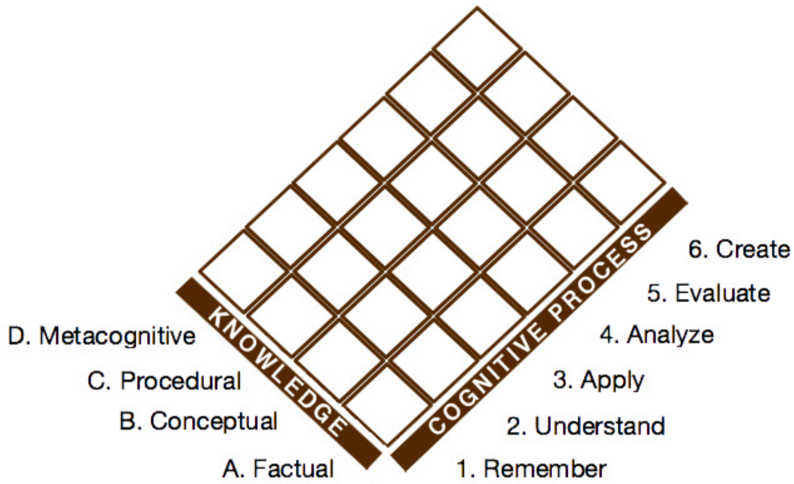
	Expert	Proficient	Intermediate	Beginner
Effectiveness of collaboration with team members and class.	Extremely Interested in collaborating in the simulation. Actively provides solutions to problems, listens to suggestions from others, attempts to refine them, monitors group progress, and attempts to ensure everyone has a contribution.	Extremely Interested in collaborating in the simulation. Actively provides suggestions and occasionally listens to suggestions from others. Refines suggestions from others.	Interested in collaborating in the simulation. Listens to suggestions from peers and attempts to use them. Occasionally provides suggestions in group discussion.	Interested in collaborating in the simulation.

(L) Teacher Resource. Mars – The Xtreme-o-philes Rubric (3 of 3)

Common Core – ELA

	Expert	Proficient	Intermediate	Beginner
Text Types and Purpose	Introduces topic clearly, provides a general observation and focus, and groups related information logically; Develops the topic with facts, definitions, concrete details, or other examples related to the topic; Links ideas using words, phrases, and clauses; Use domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic clearly, provides a general observation, or groups related information logically; Develops the topic with concrete details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; Provides a concluding statement related to the explanation.	Introduces topic, provides a general observation; Develops the topic with details, or other examples related to the topic; Links ideas using words or phrases; Uses domain-specific vocabulary to explain the topic; May or may not provide a concluding statement.	Introduces topic; Develops the topic with details, or other examples, potentially unrelated; Uses specific vocabulary to explain the topic; May or may not provide a concluding statement.
Key Ideas and Details	Uses specific evidence from text to support ideas. Develops an accurate and in depth summary, extending prior understanding and opinions.	Uses specific evidence from text to support ideas. Develops an in depth summary, extending prior understanding and opinions.	Uses information from text to support ideas. Develops a summary, extending prior understanding and opinions.	Supports ideas with details, relying on prior understanding and opinions.
Craft and Structure	Develops strong, accurate geologic vocabulary through feature identification and background research on those features.	Develops strong, geologic vocabulary through feature identification and background research on those features.	Develops vocabulary through feature identification.	Vocabulary is rudimentary toward geology and possibly based on prior understanding.

(M) 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)

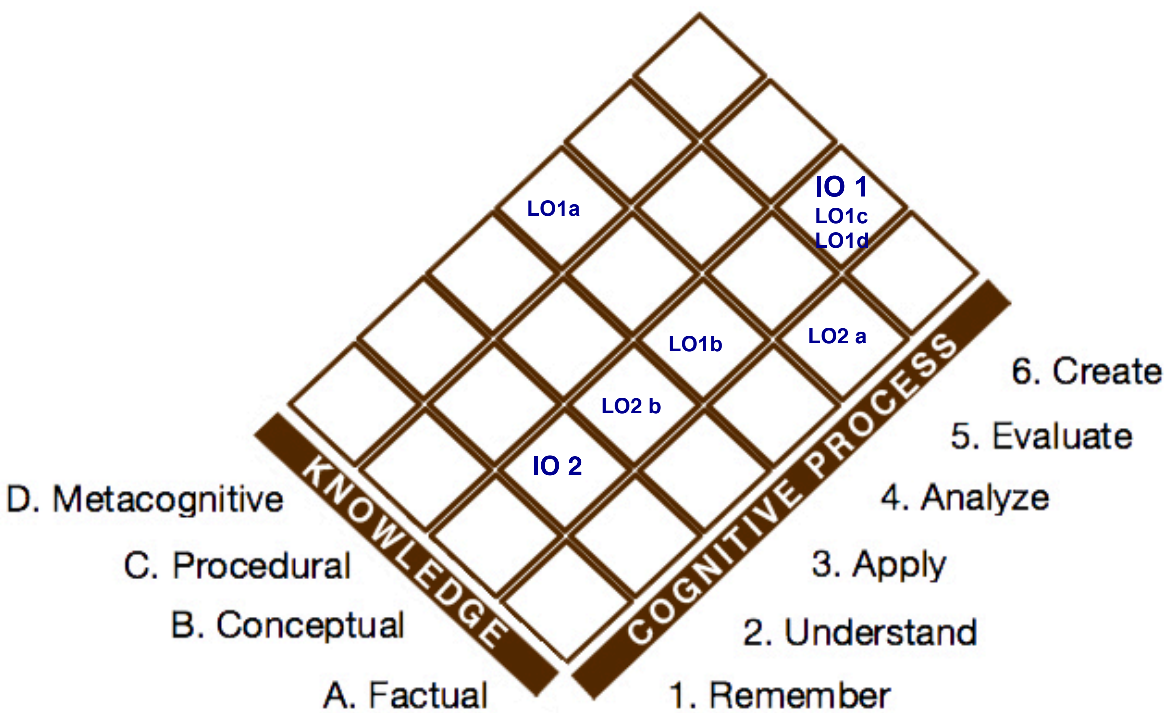
(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

IO1: to construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment. (6.3; Bc)

- **LO1a. to summarize** information regarding extremophiles that exist on Earth and about Earth and Mars environments (2.4; Ab)
- **LO1b. to recognize** the difference between living and non-living (1.1; Aa)
- **LO1c. to infer** the potential to discover life in unique and extreme environments (2.5; Bb)
- **LO1d. to differentiate** certain regions of Mars are more likely to have or once had living things, since some extremophiles are well suited to similar environments on Earth. (4.1; Db)

IO2: Use the systems' model that organisms and populations of organisms are dependent on their environmental interactions with nonliving (abiotic) factors in Earth ecosystems to predict the presence of organisms in martian environments and defend your prediction with data. (2.5; Bb)

- **LO2a. to critique** Mars environments for their potential to harbor extremophile life (5.2; Ab)
- **LO2b. to use and match** Mars environments and Earth's extremophiles looking for potential Earth life forms that could exist in specific Mars regions. (3.2; Ba)



(M) 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 (M, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (M, 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 construct an explanation based on evidence that describes how genetic variations of traits in a population increase some individuals' probability of surviving and reproducing in a specific environment.

6.3: to construct
Bc: knowledge of theories, models, and structures

IO2: Use the systems' model that organisms and populations of organisms are dependent on their environmental interactions with nonliving (abiotic) factors in Earth ecosystems to predict the presence of organisms in martian environments and defend your prediction with data.

3.1: to predict
Bb: knowledge of principles and generalizations

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

LO1a: to summarize information regarding extremophiles that exist on Earth and about Earth and Mars environments

2.4: to summarize
Ab: knowledge of specific details & elements

LO1b: to recognize the difference between living and non-living

1.1: to recognize
Aa: knowledge of terminology

LO1c: to infer the potential to discover life in unique and extreme environments

2.5: to infer
Bb: knowledge of principles and generalizations

LO1d. to differentiate certain regions of Mars are more likely to have or once had living things, since some extremophiles are well suited to similar environments on Earth.

4.1: to differentiate
Db: knowledge about cognitive tasks, including appropriate contextual and conditional knowledge

LO2a: to critique Mars environments for their potential to harbor extremophile life

5.2: to critique
Ab: knowledge of specific details & elements

LO2b: to use and match Mars environments and Earth's extremophiles looking for potential Earth life forms that could exist in specific Mars regions.

3.2: to use
Ba: Knowledge of classifications and categories