WHAT STUDENTS DO: Generate Criteria for Living vs. Non-Living.

In Part A, students will use research to develop their criteria for determining if something is alive. The class will combine their ideas in a teacher-guided discussion. In Part B, they will then use their criteria to determine whether there is anything alive in three different soil samples. They will make observations and draw pictures as they collect data from the sample and investigation. The purpose of this lesson is for students to use a critical thinking and a collaborative approach to identifying and applying the criteria needed for life. Students will:

- Use scientific observations to establish criteria;
- Differentiate between living and non-living objects; and
- Attribute criteria as Earth-based definitions of life.

NGSS CORE & COMPONENT QUESTIONS

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 do matter and energy move through an ecosystem?
NGSS LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

INSTRUCTIONAL OBJECTIVES

Students will be able

IO1: to conduct and investigation to generate a list of criteria for determining if something is alive
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


- 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*


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 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 DO MATTER AND ENERGY MOVE THROUGH AN ECOSYSTEM?

**NGSS LS2.B: Cycles of Matter and Energy Transfer in Ecosystems**

<table>
<thead>
<tr>
<th>Instructional Objective</th>
<th>Learning Outcomes</th>
<th>Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td>Students will be able</td>
<td>Students will demonstrate the measurable abilities</td>
<td></td>
</tr>
</tbody>
</table>

**IO1:**

to conduct an investigation to generate a list of criteria for determining if something is alive

- **LO1a.** to use scientific observations of phenomena to guide the criteria development
- **LO1b.** to differentiate and justify between living and non-living objects
- **LO1c.** to attribute the established criteria to life as we know it on Earth

**Standards**

**NGSS Disciplinary Core Idea:**

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

**NGSS Practices:**

Analyzing and Interpreting Data  
Constructing Explanations and Designing Solutions  
Engaging in Argument from Evidence  
Scientific Knowledge is Open to Revision in Light of the New Evidence

**NGSS Cross-Cutting Concept:**

Cause and Effect  
Systems and System Models  
Energy and Matter
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.

- **LO1a**: to use scientific observations of phenomena to guide the criteria development
- **LO1b**: to differentiate and justify between living and non-living objects
- **LO1c**: to attribute the established criteria to life as we know it on Earth

The Partnership for 21st Century Skills
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.


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 conduct an investigation to generate a list of criteria for determining if something is alive**

**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-LS2-3)

**Next Generation Science Standards (NGSS) Practices: Analyzing and Interpreting Data – Grades 9-12**  
(Learning Outcomes Addressed: LO1a, LO1b)

- Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution.
- Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations.

**Next Generation Science Standards (NGSS) Practices: Constructing Explanations and Designing Solutions – Grades 9-12**  
(Learning Outcomes Addressed: LO1b, LO1c)

- Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects.
- Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion.

**Next Generation Science Standards (NGSS) Practices: Engaging in Argument from Evidence – Grades 9-12**  
(Learning Outcomes Addressed: LO1b, LO1c)

- 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.

• Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence.

• Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge and student-generated evidence.

Next Generation Science Standards (NGSS)
Practices: Scientific Knowledge is Open to Revision in Light of New Evidence – Grades 9-12
(Learning Outcomes Addressed: LO1b, LO1c)

• Most scientific knowledge is quite durable but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.

• Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of an explanation.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Cause and Effect – Grades 9-12
(Learning Outcomes Addressed: LO1a, LO1b)

• 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 – Grades 9-12
(Learning Outcomes Addressed: LO1b, LO1c)

• Students can investigate or analyze a system by defining its boundaries and initial conditions, as well as its inputs and outputs. They can use models (e.g., physical, mathematical, computer models) to simulate the flow of energy, matter, and interactions within and between systems at different scales. 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)
Cross-Cutting Concepts: Energy and Matter – Grades 9-12
(Learning Outcomes Addressed: LO1a)
• Students learn that the total amount of energy and matter in closed systems is conserved. They can describe changes of energy and matter in a system in terms of energy and matter flows into, out of, and within that system. They also learn that energy cannot be created or destroyed. It only moves between one place and another place, between objects and/or fields, or between systems. Energy drives the cycling of matter within and between systems. In nuclear processes, atoms are not conserved, but the total number of protons plus neutrons is conserved.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
(Learning Outcomes Addressed: LO1b, LO1c)

• Photosynthesis and cellular respiration (including anaerobic processes) provide most of the energy for life processes.

Common Core State Standards
Writing for Literacy in Science and Technical Subjects Standards 9-12: Text Types and Purposes
(Learning Outcomes Addressed: LO1b, LO1c)

• Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Grade 9-10)
  o 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.
  o 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.
  o Use varied transitions and sentence structures to link the major sections of the text, create cohesion, and clarify the relationships among ideas and concepts.
  o 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.
  o Establish and maintain a formal style and objective tone while attending to the norms and conventions of the discipline in which they are writing.
  o 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)
• Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes. (Grade 11-12)
  o 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.
  o 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.
  o 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.
  o 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.
  o 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)

21st Century Skills
Collaboration
(Learning Outcomes Addressed: LO1a)

  o Students collaborate with peers and experts during scientific discourse and appropriately defend arguments using scientific reasoning, logic, and modeling. (Grade 12 Benchmark)
### Learning Outcomes Assessment:

<table>
<thead>
<tr>
<th>LO1a: to use scientific observations of phenomena to guide the criteria development</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria list correlates to specific scientific observations and inferences made during exploration.</td>
<td></td>
<td></td>
<td>Criteria list correlates to scientific observations and misinterpretations</td>
<td>Criteria list correlates to student preconceptions and misinterpretations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LO1b: to differentiate and justify between living and non-living objects</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Criteria list is used to correctly identify living organisms vs. non-living objects and further discriminates objects that are “close” to living, but not meeting all of the criteria, as non-living</td>
<td>Criteria list is used to correctly identify living organisms vs. non-living objects.</td>
<td>Criteria list is loosely used to identify living vs. non-living objects.</td>
<td>Identification of living vs. non-living is based on preconceptions such as movement, having eyes, talking and eating.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>LO1c: to attribute the established criteria to life as we know it on Earth</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thoughtful examples are given of objects on Earth that do not meet the criteria of living based on Earth’s standards. Recognizes that new “objects” may redefine the criteria used to identify “living”</td>
<td>Examples of objects on Earth that do not meet the criteria of living based on Earth’s standards are recorded. Recognizes that new “objects” may redefine the criteria used to identify “living”</td>
<td>Examples of objects on Earth that do not meet the criteria of living based on Earth’s standards are recorded.</td>
<td>Identification examples of living vs. non-living is based on preconceptions such as movement, having eyes, talking and eating.</td>
<td></td>
</tr>
</tbody>
</table>
### Partnership for 21st Century Skills

<table>
<thead>
<tr>
<th>Effectiveness of collaboration with team members and class.</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>Extremely interested in collaborating in the simulation. Actively provides suggestions and occasionally listens to suggestions from others. Refines suggestions from others.</td>
<td>Interested in collaborating in the simulation. Listens to suggestions from peers and attempts to use them. Occasionally provides suggestions in group discussion.</td>
<td>Interested in collaborating in the simulation.</td>
<td></td>
</tr>
</tbody>
</table>
## Common Core – ELA

<table>
<thead>
<tr>
<th>Text Types and Purpose</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>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.</td>
<td>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.</td>
<td>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.</td>
<td>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.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Effective Demonstration of Comprehension and Collaboration</th>
<th>Expert</th>
<th>Proficient</th>
<th>Intermediate</th>
<th>Beginner</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clearly articulates ideas in collaborative discussion while following agreed upon class rules for discussion. Extremely prepared drawing from experiences. Asks clarifying questions to ensure full understanding of content. Articulates own ideas related to the discussion and connects others ideas to own.</td>
<td>Articulates ideas in collaborative discussion while following agreed upon class rules for discussion. Prepared for discussion by drawing from experiences. Asks questions. Articulates own ideas related to the discussion.</td>
<td>Interested in collaborative discussion. Asks questions. Articulates own ideas related to the discussion.</td>
<td>Interested in collaboration with peers.</td>
<td></td>
</tr>
</tbody>
</table>
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.

<table>
<thead>
<tr>
<th>Knowledge</th>
<th>Cognitive Process</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>A. Factual</strong></td>
<td>1. <strong>Remember</strong></td>
</tr>
<tr>
<td>Aa: Knowledge of Terminology</td>
<td>1.1 Recognizing (Identifying)</td>
</tr>
<tr>
<td>Ab: Knowledge of Specific Details &amp; Elements</td>
<td>1.2 Recalling (Retrieving)</td>
</tr>
<tr>
<td><strong>B. Conceptual</strong></td>
<td>2. <strong>Understand</strong></td>
</tr>
<tr>
<td>Ba: Knowledge of classifications and categories</td>
<td>2.1 Interpreting (Clarifying, Paraphrasing, Representing, Translating)</td>
</tr>
<tr>
<td>Bb: Knowledge of principles and generalizations</td>
<td>2.2 Exemplifying (Illustrating, Instantiating)</td>
</tr>
<tr>
<td>Bc: Knowledge of theories, models, and structures</td>
<td>2.3 Classifying (Categorizing, Subsuming)</td>
</tr>
<tr>
<td><strong>C. Procedural</strong></td>
<td>3. <strong>Apply</strong></td>
</tr>
<tr>
<td>Ca: Knowledge of subject-specific skills and algorithms</td>
<td>3.1 Executing (Carrying out)</td>
</tr>
<tr>
<td>Cb: Knowledge of subject-specific techniques and methods</td>
<td>3.2 Implementing (Using)</td>
</tr>
<tr>
<td>Cc: Knowledge of criteria for determining when to use appropriate procedures</td>
<td>4. <strong>Analyze</strong></td>
</tr>
<tr>
<td><strong>D. Metacognitive</strong></td>
<td>4.1 Differentiating (Discriminating, distinguishing, focusing, selecting)</td>
</tr>
<tr>
<td>Da: Strategic Knowledge</td>
<td>4.2 Organizing (Finding coherence, integrating, outlining, parsing, structuring)</td>
</tr>
<tr>
<td>Db: Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge</td>
<td>4.3 Attributing (Deconstructing)</td>
</tr>
<tr>
<td>Dc: Self-knowledge</td>
<td>5. <strong>Evaluate</strong></td>
</tr>
<tr>
<td></td>
<td>5.1 Checking (Coordinating, Detecting, Monitoring, Testing)</td>
</tr>
<tr>
<td></td>
<td>5.2 Critiquing (Judging)</td>
</tr>
<tr>
<td></td>
<td>6. <strong>Create</strong></td>
</tr>
<tr>
<td></td>
<td>6.1 Generating (Hypothesizing)</td>
</tr>
<tr>
<td></td>
<td>6.2 Planning (Designing)</td>
</tr>
<tr>
<td></td>
<td>6.3 Producing (Constructing)</td>
</tr>
</tbody>
</table>
(M) Teacher Resource. Placement of Instructional Objective and Learning Outcomes in Taxonomy (2 of 3)

IO1: to generate a list of criteria for determining if something is alive (6.1; Bc)

- LO1a. to use scientific observations of phenomena to guide the scientific question (3.2; Bc)
- LO1b. to differentiate and justify between living and non-living objects (4.1; Cc)
- LO1c. to attribute the established criteria to life as we know it on Earth (4.3; Db)
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 generate a list of criteria for determining if something is alive

**6.1:** to generate

**Bc:** knowledge of theories, models, and structures

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

**LO1a:** to use scientific observations of phenomena to guide the scientific question

**3.2:** to use

**Bc:** knowledge of theories, models, and structures

**LO1b:** to differentiate between living and non-living objects

**4.1:** to differentiate

**Cc:** knowledge of criteria for determining when to use appropriate procedures

**LO1c:** to attribute the established criteria to life as we know it on Earth

**4.3:** to attribute

**Db:** Knowledge about cognitive tasks, including appropriate contextual and conditional knowledge