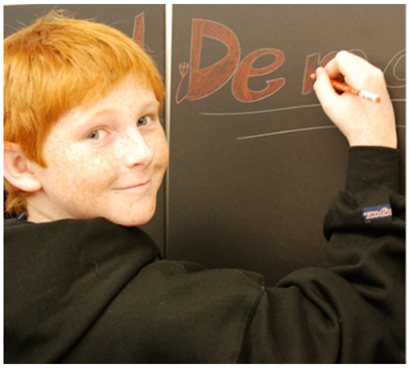
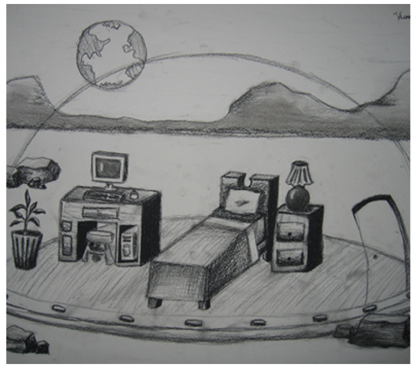
Follow Your Curiosity: A 2012 NASA Summer of Innovation Collection

Lesson 12

Imagining Sustainable Communities on Mars

Grades: 6-8 Prep Time: 5 Minutes Lesson Time: 2-3 Hours


WHAT STUDENTS DO: Brainstorm Designs

Curiosity goes hand in hand with imagination. Students brainstorm the environmental and cultural requirements for a community. Next, learners develop potential solutions and technologies to meet the identified community requirements. Students create draft designs that address these requirements and evaluate them. Based on criteria, students determine which design elements are the best. In this collection, this lesson provides a synthesis and summative experience for students, allowing them to share their newly developed problem-solving skills and their design-based solutions with others. It originates from the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts: http://imaginemars.jpl.nasa.gov

NRC CORE & COMPONENT QUESTIONS

HOW DO ENGINEERS SOLVE PROBLEMS?

NRC Core Question: ETS1: Engineering Design

What Is a Design for? What are the criteria and constraints of a successful solution?

NRC ETS1.A: Defining & Delimiting an Engineering Problem

What Is the Process for Developing Potential Design Solutions?

NRC ETS1.B: Developing Possible Solutions

INSTRUCTIONAL OBJECTIVES

Students will be able

IO2: to evaluate

proposed solutions in a design task per requirements and constraints

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

This activity is part of the Imagine Mars Project, co-sponsored by NASA and the National Endowment for the Arts (NEA). The Imagine Mars Project is a hands-on, STEM-based project that asks students to work with NASA scientists and engineers to imagine and to design a community on Mars using science and technology, then express their ideas through the arts and humanities, integrating 21st Century skills. The Imagine Mars Project enables students to explore their own community and decide which arts-related, scientific, technological, and cultural elements will be important on Mars. Then, they develop their concepts relating to a future Mars community from an interdisciplinary perspective of the arts, sciences, and technology. imaginemars.jpl.nasa.gov

The Imagine 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 Imagine Mars instructional series. The 5E stages can be cyclical and iterative.

2.0 Materials

Required Materials

Please supply:

- Paper, pencils, and erasers
- Sticky notes (at least 10 per pair of students)
- Large chart paper
- Communities students developed in the REFLECT stage of the lessons

Please Print:

From Prior Activity

- Copies of students' draft community plan from Reflect lesson

From Student Guide

(A) Rules for Brainstorming – 1 per student
(B) Draft Community Evaluation Checklist – 1 per team

Optional Materials

From Teacher Guide

(C) Draft Community Evaluation Checklist - Example
(D) "Imagine" Assessment Rubrics
(E) Alignment of Instructional Objective(s) and Learning Outcome(s) with Knowledge and Cognitive Process Types

3.0 Vocabulary

Analyze	consider data and results to look for patterns and to compare possible **solutions**
Ask questions	scientists asks questions that can be answered using **empirical evidence**
Constraints	restricting or limiting circumstances
Design Criteria	the standards that are used to judge a proposal
Empirical Evidence	the standards that are used to judge a proposal
Explanations	logical descriptions applying scientific and technological information
Evaluate	check the scientific validity or soundness

Hypothesis	a suggested explanation that can be shown to be valid or not through evidence
Imagine	envision objects or processes that cannot be seen
Investigation	an exploration of a topic or question to gain information
Models	a simulation that helps explain natural and man-made systems and shows possible flaws
Predict	a declaration about what will happen based on reason and knowledge
Reasoning	reaching conclusions based on facts
Safety	not causing injury, danger, or loss
Solutions	the best choice given the criteria and constraints of the problem
Technological feasibility	probable, can be done

4.0 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:

ETS1A:

HOW DO ENGINEERS SOLVE PROBLEMS? *NRC Core Question: ETS1: Engineering Design* **What Is a Design for? What are the criteria and constraints of a successful solution?** *NRC Component Question ETS1.A: Defining & Delimiting an Engineering Problem*			
Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **to evaluate** proposed solutions in a design task using criteria	**LO1a. to identify** environmental constraints and cultural and other requirements **LO1b. to develop** acceptable measures **LO1c. to compare** proposed solutions	**NSES (E): SCIENCE & TECHNOLOGY: Abilities of Technological Design** **Grades 5-8:** E1b: Design a Solution or a Product	**Rubrics in Teacher Guide**

ETS1B:

HOW DO ENGINEERS SOLVE PROBLEMS? *NRC Core Question: ETS1: Engineering Design* **What Is the Process for Developing Potential Design Solutions?** *NRC ETS1.B: Developing Possible Solutions*			
Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **to evaluate** proposed solutions in a design task using criteria	**LO1d. to judge** community designs using criteria **LO1e. to modify** community designs using criteria	**NSES (E): SCIENCE & TECHNOLOGY: Abilities of Technological Design** **Grades 5-8:** E1d: Evaluate Completed Technological Designs or Products	**Rubrics in Teacher Guide**

5.0 Procedure

PREPARATION (~5 minutes)

A. Make copies of:

- (A) Rules for Brainstorming – 1 per student
- (B) Community Evaluation Checklist – 1 per student
- (D) "Imagine" Assessment Rubrics – 1 per student

STEP 1: ENGAGE (~10 minutes)

Brainstorm "environmental and cultural requirements."

A. Give each student a copy of *(D) "Imagine" Rubric* to review expectations.

B. Using community designs from REFLECT (see Lesson 1 in this Collection), students brainstorm a list of requirements for life on Mars and environmental and other constraints.

Example: Ideas might include size of community, each environmental constraint, cultural elements such as music concert halls or art galleries, etc.

C. List their ideas on the board.

Teacher Tip: To increase metacognition, ask students to use the rubric to assess themselves on their lists of requirements.

D. Ask students to reflect on the DISCOVER note-taking sheet (see Lesson 4 in this collection) and think about all of the environmental constraints. Are they all included in the list?

E. Ask students to consider cultural elements such as art, music, government, & leadership, etc. Are those captured in the list?

F. Write one requirement as a heading for each piece of chart paper. Hang the posters around the room.

STEP 2: EXPLORE (~10 minutes)

Brainstorm Solutions.

A. Refer students to the different posters.

B. Challenge students, working in pairs, to brainstorm solutions for each requirement and constraint and write their ideas on sticky notes. Have students hang their ideas on the appropriate poster.

Encourage students to consider how they would get different resources, use different resources, and include cultural elements that make a community thrive.

Example: Students might have an idea for a giant catapult to throw ice chunks closer to the community. This idea would be placed on the "water" poster.

C. Review *(A) Rules for Brainstorming*. Explain that you will read the ideas, and if somebody has something to add or a completely different idea to offer, that person should share it with the group.

D. Share the solution ideas on each poster, asking students to make note of solutions they want to use for their communities. Discuss how feasible different solutions might be. Ask if any current technologies can make each solution possible.

Teacher Tip: Consider using a Solar System Ambassador or a scientist to give expert advice. Solar System Ambassadors are volunteers with space science expertise, willing to help in your classroom. Go to http://www2.jpl.nasa.gov/ambassador/directory.htm to find Solar System Ambassadors in your area.

STEP 3: EXPLAIN (~10 minutes)
Create a model/design with criteria.

A. Give students the copies of *(B) Draft Community Evaluation Checklist*. Have them fill in the problems in the criteria column. These are now the design criteria for measuring the feasibility of their community on Mars

B. Direct students to design at least 2 drawings of possible changes to their REFLECT (see Lesson 1 in this Collection) community designs.

C. They will determine which design is better by evaluating which one best helps the community meet the requirements.

STEP 4: ELABORATE (~10 minutes)
Revise models based on other's ideas.

A. Give students time to complete their draft design ideas.

B. Half way through the drafting process, allow students to walk around the classroom to see other projects for inspiration.

C. Explain that they can revise their models based on their peers' ideas.

STEP 5: EVALUATE (~60 minutes)

Evaluate proposed solutions using criteria.

A. Review the criteria list with students.

B. Have students use the *(B) Draft Community Evaluation Checklist* to determine which design best meets the criteria.

Teacher Tip: You may want to show students *(C) Community Evaluation Checklist Example*.

C. Tell students that they will be making 3-dimensional models of their designs. They can combine elements from their 2 drafts today and add or change any part of the design.

D. Collect student work and rubrics to evaluate their proficiency per rubrics

6.0 Extensions

Have students use criteria to judge anonymously other teams' projects, using a point system. Collect the results for each team, and have them add up the points. Find out which design is most optimal based on the criteria and the number of points.

7.0 Evaluation/Assessment

Use the *(B) Draft Community Evaluation Checklist* as a formative and summative assessment, allowing students to improve their work and learn from mistakes during class. The checklist evaluates the activities using the NRC Framework and National Science Education Standards.

8.0 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/

wikiHOW. (2011, November 9). *How to do a presentation in class*. Retrieved January 18, 2012 from http://www.wikihow.com/Do-a-Presentation-in-Class

(A) Student Handout. Rules for Brainstorming

1. **Avoid Critique.**
   It is hard to be creative when you feel unsafe or judged. Ideas have to spring out and allow others to build on them. A good idea can come from a completely crazy thought. Every person should feel comfortable sharing any idea.

2. **Foster outrageous ideas.**
   Crazy thoughts allow others to consider different perspectives and break out of their shells. When considering a wild idea, we think about the constraints and criteria; it helps use define what we truly want.

3. **Add to others' ideas.**
   The goal is to be positive and encouraging of others' ideas so we can jump start our own minds. Try to avoid saying, "but" or "no" and focus on saying "and" or "yes."

4. **Stay on target.**
   Keep your comments on the task and avoid distracting the group.

5. **Focus discussion.**
   Wait your turn. Jot down ideas you are afraid you might forget, and be sure that your ideas relate to the topic. If a group member mentions an idea that seems off task, ask yourself if there is a way it might relate.

6. **Be visual.**
   Use pictures, graphic organizers and colors in your idea sharing. It is okay if you are not an artist! The big ideas behind your artwork or graphic description are what matter.

7. **More is more.**
   Try to share as many ideas as possible. The more ideas you have, the more likely you are to have many good ideas!

Source: http://www.openideo.com/fieldnotes/openideo-team-notes/seven-tips-on-better-brainstorming

(B) Student Worksheet. Community Evaluation Checklist

Directions: In the Criteria Column, fill in the criteria, one per line. In the Draft #1 Column, place a ✓ in the box if your design meets each criterion, leave it blank if your design does not meet the criterion. Do the same for Draft #2.

Criteria	Draft #1	Draft #2

(C) Community Evaluation Checklist Example

Directions: In the Criteria Column, fill in the criteria, one per line. In the Draft #1 Column, place a ✓ in the box if your design meets each criterion, leave it blank if your design does not meet the criterion. Do the same for Draft #2.

Criteria	Draft #1	Draft #2
A way for people in your community to get oxygen	✓	✓
Protection from radiation	✓	
Plan to get and use water	✓	✓
Food sources		✓
Protection from dust	✓	✓
Heat source		
Energy source		✓
Housing	✓	✓
Movie Center		✓
Culinary arts area	✓	

(D) Teacher Resource. Imagine Rubric (1 of 2)

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 evaluate proposed solutions in a design task

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

National Science Education Standards (NSES)
(E) Science and Technology: Abilities of Technological Design
Design a solution or a product. Students should make and compare different proposals in the light of the criteria they have selected. They must consider constraints such as cost, time, trade-offs, and materials needed and communicate ideas with drawings and simple models. (Grades 5-8: E1b)

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: Identify environmental constraints and cultural and other requirements	List includes maximum and thoughtful items.	List includes many items.	List includes some items.	List includes a few items.
LO1b: Develop acceptable measures	Sticky notes reflect a maximum of thoughtful, appropriate solutions to community requirements	Sticky notes reflect a many thoughtful, appropriate solutions to community requirements	Sticky notes reflect some appropriate solutions to community requirements	Sticky notes reflect few appropriate solutions to community requirements
LO1c: Compare and choose proposed solutions	Solution choices are thoughtful, reasonable and address community requirements.	Solution choices are reasonable and address community requirements.	Solution choices are mostly reasonable and address community requirements.	Solution choices are not reasonable or do not address community requirements.

(D) Teacher Resource. Imagine Rubric (2 of 2)

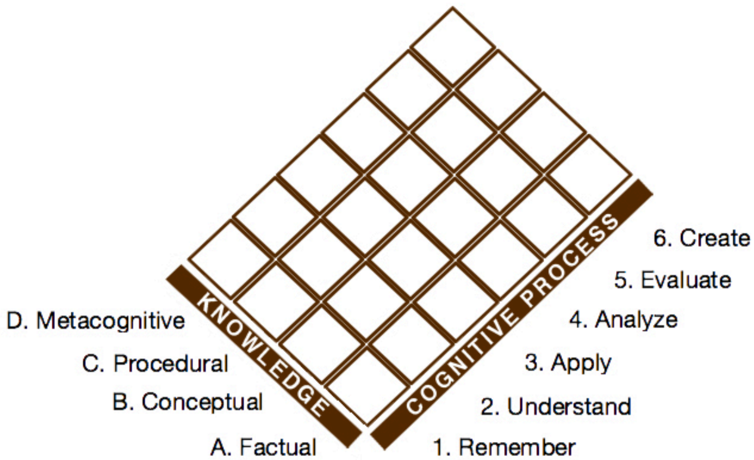
Related Standard(s) (will be replaced when new NRC Framework-based science standards are released):

National Science Education Standards (NSES)
(E) Science and Technology: Abilities of Technological Design
Evaluate completed technological designs or products. 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
LO1d: Judge community designs using criteria (checklist)	Checklist accurately and honestly evaluates both communities.	Checklist accurately evaluates both communities.	Checklist evaluates both communities with few mistakes.	Checklist evaluates both communities with numerous mistakes.
LO1e. Modify community designs using criteria	Modifications are innovative and fully match criteria.	Modifications are innovative and mostly match criteria.	Modifications somewhat match criteria.	Modifications do not match criteria.

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

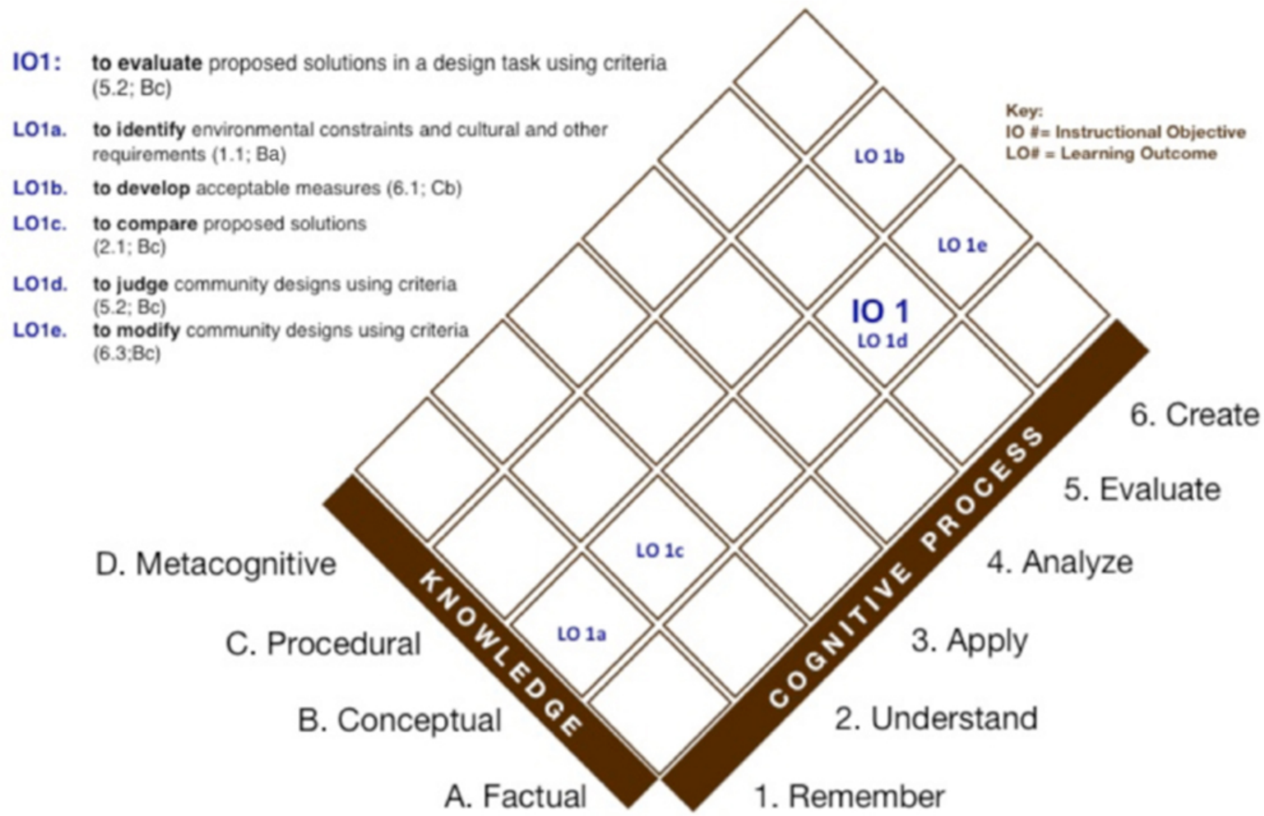


This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s).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

(E) 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.



(E) 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 (E, 1 of 3) for the full list of categories in the taxonomy from which the following were selected. The prior page (E, 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 evaluate solutions

- **5.2:** to evaluate
- **Bc:** knowledge of theories, models, and structures

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

LO1a: to identify constraints/requirements

- 1.1: to identify
- Ba: knowledge of classifications and categories

LO1b: to develop measures

- 6.1: to develop
- Cb: knowledge of subject specific techniques and methods

LO1c: to compare solutions

- 2.1: to compare
- Bc: knowledge of theories, models, and structures

LO1d: to judge designs with criteria

- 5.2: to judge
- Bc: knowledge of theories, models, and structures

LO1e: to modify using criteria

- 6.3: to modify
- Bc: strategic knowledge