Rover Races

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

WHAT STUDENTS DO: Establishing Communication Procedures.

Following Curiosity on Mars often means roving to places with interesting materials to study, places away from the initial landing site. In this lesson, students experience the processes involved in engineering a communication protocol. To reach their goal, students must create a calibrated solution within constraints and parameters of communicating with a rover on Mars. In this collection, this activity continues to build students' understanding of engineering design in pursuit of scientific objectives.

NRC CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
HOW DO ENGINEERS SOLVE PROBLEMS? *NRC Core Question: ETS1: Engineering Design*	*Students will be able*
What is a design for? What are the criteria and constraints of a successful solution? *NRC ETS1.A: Defining & Delimiting an Engineering Problem*	**IO1: to apply** the engineering design cycle to produce an engineering design that meets mission goals within constraints.
What is the process for developing potential design solutions? *NRC ETS1.B: Developing Possible Solutions*	
How can the various proposed design solutions be compared and improved? *NRC ETS1.C: Optimizing the Design Solution*	

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 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

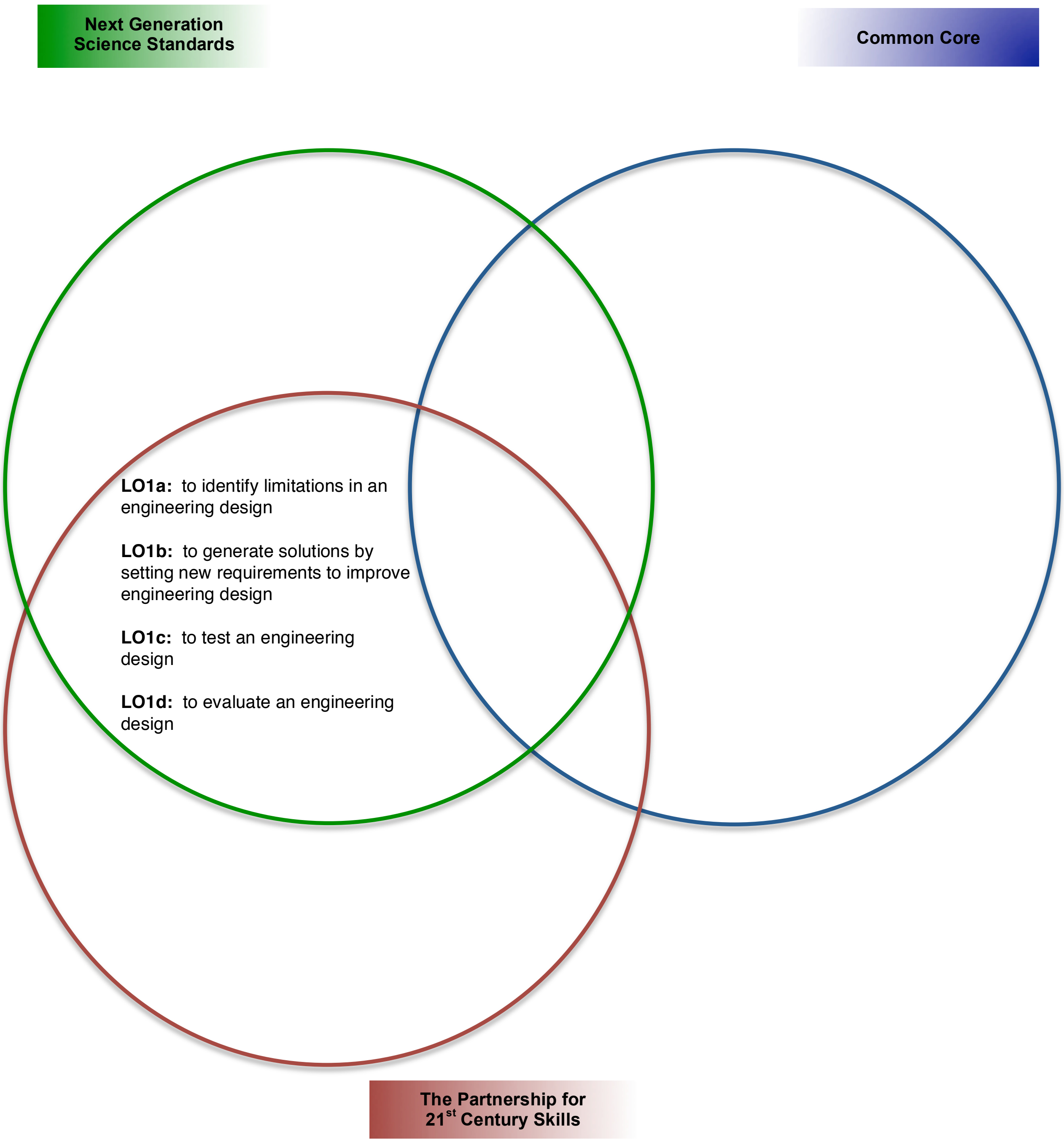
How can the various proposed design solutions be compared and improved?

NRC ETS1.C: Optimizing the Design Solution

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*
IO1: **to apply** the engineering design cycle to produce an engineering design that meets mission goals within constraints.	**LO1a: to identify** limitations in an engineering design **LO1b: to generate** solutions by setting new requirements to improve engineering design **LO1c: to test** an engineering design **LO1d: to evaluate** an engineering design	**NSES (E): SCIENCE AS INQUIRY:** **Abilities of Technological Design** **Grades 5-8:** E1b, E1c, E1d **Understandings about Science & Technology** **Grades 5-8:** E2e **NGSS Practices:** **Asking Questions and Defining Problems** **Developing and Using Models** **Planning and Carrying out Investigations** **Analyzing and Interpreting Data** **Constructing Explanations and Designing Solutions** **Engaging in an Argument from Evidence** **NGSS Cross-Cutting Concept:** **Structure and Function** **Systems and System Models**

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. Rover Races 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 apply the engineering design cycle to produce an engineering design that meets mission goals within constraints.

Related Standard(s)

National Science Education Standards (NSES)
(E) Science and Technology: Abilities of Technological Design
Design a Solution or Product. Students should make and compare different proposals in 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)

Implement a Proposed Design. Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy. (Grades 5-8: E1c)

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)

National Science Education Standards (NSES)
(E) Science and Technology: Understandings About Science & Technology
Technological designs have constraints. Some constraints are unavoidable, for example, properties of materials or effects of weather and friction; other constraints limit choices in the design, for example, environmental protection, human safety, and aesthetics. (Grades 5-8: E2e)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below: (MS-ETS1-1); (MS-ETS1-2); (MS-ETS1-3); (MS-ETS1-4)

Next Generation Science Standards (NGSS)
Practices: Asking Questions and Defining Problems
(Learning Outcomes Addressed: LO1a, LO1b, LO1d)

- Ask questions
    - that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information.

  - to identify and/or clarify evidence and/or the premise(s) of an argument.
  - to clarify and/or refine a model, an explanation, or an engineering problem.
- Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions.

Next Generation Science Standards (NGSS)
Practices: Developing and Using Models
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Evaluate limitations of a model for a proposed object or tool.
- Develop and/or use a model to generate data to test ideas about phenomena in natural or designed systems, including those representing inputs and outputs, and those at unobservable scales.

Next Generation Science Standards (NGSS)
Practices: Planning and Carrying out Investigations
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Conduct an investigation and/or evaluate and/or revise the experimental design to produce data to serve as the basis for evidence that meet the goals of the investigation.
- Collect data to produce data to serve as the basis for evidence to answer scientific questions or test design solutions under a range of conditions.
- Collect data about the performance of a proposed object, tool, process or system under a range of conditions.

Next Generation Science Standards (NGSS)
Practices: Analyzing and Interpreting Data
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Analyze and interpret data to provide evidence for phenomena.
- Consider limitations of data analysis (e.g., measurement error), and/or seek to improve precision and accuracy of data with better technological tools and methods (e.g., multiple trials).
- Analyze and interpret data to determine similarities and differences in findings.
- Analyze data to define an optimal operational range for a proposed object, tool, process or system that best meets criteria for success.

Next Generation Science Standards (NGSS)
Practices: Constructing Explanations and Designing Solutions
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Construct an explanation using models or representations.
- Apply scientific ideas or principles to design, construct, and/or test a design of an object, tool, process or system.
- Undertake a design project, engaging in the design cycle, to construct and/or implement a solution that meets specific design criteria and constraints.
- Optimize performance of a design by prioritizing criteria, making tradeoffs, testing,

revising, and re-testing.

Next Generation Science Standards (NGSS)
Practices: Engaging in Argument from Evidence
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Respectfully provide and receive critiques about one's explanations, procedures, models, and questions by citing relevant evidence and posing and responding to questions that elicit pertinent elaboration and detail.
- Construct, use, and/or present an oral and written argument supported by empirical evidence and scientific reasoning to support or refute an explanation or a model for a phenomenon or a solution to a problem.
- Make an oral or written argument that supports or refutes the advertised performance of a device, process, or system based on empirical evidence concerning whether or not the technology meets relevant criteria and constraints.
- Evaluate competing design solutions based on jointly developed and agreed-upon design criteria.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Systems and System Models
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students can understand that systems may interact with other systems; they may have sub-systems and be a part of larger complex systems. They can use models to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. They can also learn that models are limited in that they only represent certain aspects of the system under study.

Next Generation Science Standards (NGSS)
Cross-Cutting Concepts: Structure and Function
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students model complex and microscopic structures and systems and visualize how their function depends on the shapes, composition, and relationships among its parts. They analyze many complex natural and designed structures and systems to determine how they function. They design structures to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ETS1.A: Defining and Delimiting Engineering Problems
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ETS1.B: Developing Possible Solutions
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it.
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem.
- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors.
- Models of all kinds are important for testing solutions.

Next Generation Science Standards (NGSS)
Disciplinary Core Idea: ETS1.C: Optimizing the Design Solution
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design.
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution.

21st Century Skills
Critical Thinking
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students plan and conduct scientific investigations and write detailed explanations based on their evidence. Students compare their explanations to those made by scientists and relate them to their own understandings of the natural and designed worlds. (8th Grade Benchmark)

21st Century Skills
Creativity and Innovation
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students are able to describe how science and engineering involve creative processes that include generating and testing ideas, making observations, and formulating explanations; and can apply these processes in their own investigations. (Grade 8 Benchmark)

21st Century Skills
Collaboration
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students work collaboratively with others, either virtually or face-to-face, while participating in scientific discussions and appropriately using claims, evidence, and reasoning. (Grade 8 Benchmark)

21st Century Skills
Social and Cross-Cultural
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students are able to structure scientific discussions to allow for differing opinions, observations, experiences, and perspectives. (8th Grade Benchmark)

(D) Teacher Resource. Rover Races Rubric (1 of 2)

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

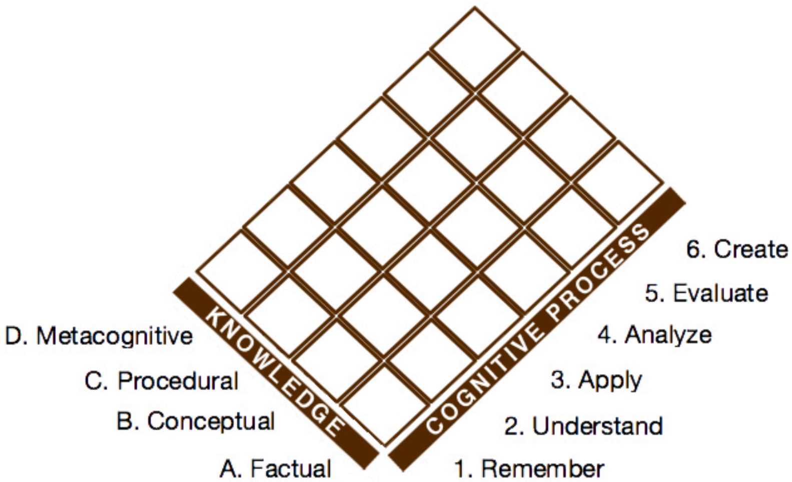
Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to identify limitations in an engineering design (rover command sequence)	Limitations identified are accurate, complete, and logical to the group and individual observations made during the process.	Limitations are accurate, and mostly complete and logical. Limitations relate to group and/or individual observations made.	Most limitations are accurate and complete and relate to the observations made.	Limitations are listed and mostly individual observations.
LO1b: to generate solutions by setting new requirements to improve engineering design (command sequence)	Solutions are firmly based on criteria. Criteria reflect observations and limitations identified and support the solutions presented.	Solutions are based on criteria. Criteria reflect observations and limitations and support many of the solutions presented.	Solutions are loosely based criteria. Criteria reflect observations and may or may not support the solution presented.	Solutions are presented. Criteria are listed.
LO1c: to test an engineering design	Tests result in significant improvement in design (goal achievement in completing the course).	Tests result in improvement in design (goal achievement in completing the course).	Tests result in moderate improvement in design (goal achievement in completing the course).	Tests are performed for personal gain or entertainment value.
LO1d: to evaluate an engineering design (acceptable rover commands to complete a course)	Evaluation is extremely clear and complete, with design changes, criteria and limitations well documented and thoughtful.	Evaluation is clear and complete, with design changes, criteria, and limitations documented.	Evaluation is complete, with supporting design changes documented.	Short evaluation is presented with explanation of a design change.

(L) Teacher Resource Rover Races Rubric (2 of 2)

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.
Effectiveness in communication	Communicates ideas in a clearly organized and logical manner that is consistently maintained.	Communicates ideas in an organized manner that is consistently maintained.	Communications of ideas are organized, but not consistently maintained.	Communicates ideas as they come to mind.
Effectiveness of critical thinking	Develops detailed explanations based on credible evidence. Compares explanations to those made by peers and relates them to their new understandings.	Develops detailed explanations based on credible evidence. Relates them to their new understandings.	Develops explanations. Relates explanation to their new understandings.	Attempts to explain the design based on own preconceived understanding.
Effectiveness of Creativity, Innovation and Flexibility	Demonstrates a wide variety of generating and testing of ideas to achieve a successful mission goal.	Demonstrates a variety of generating and testing of ideas to achieve a successful mission goal.	Demonstrates a wide variety ideas to achieve a successful mission goal.	Demonstrates a ideas to achieve a design for personal gain or entertainment.

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



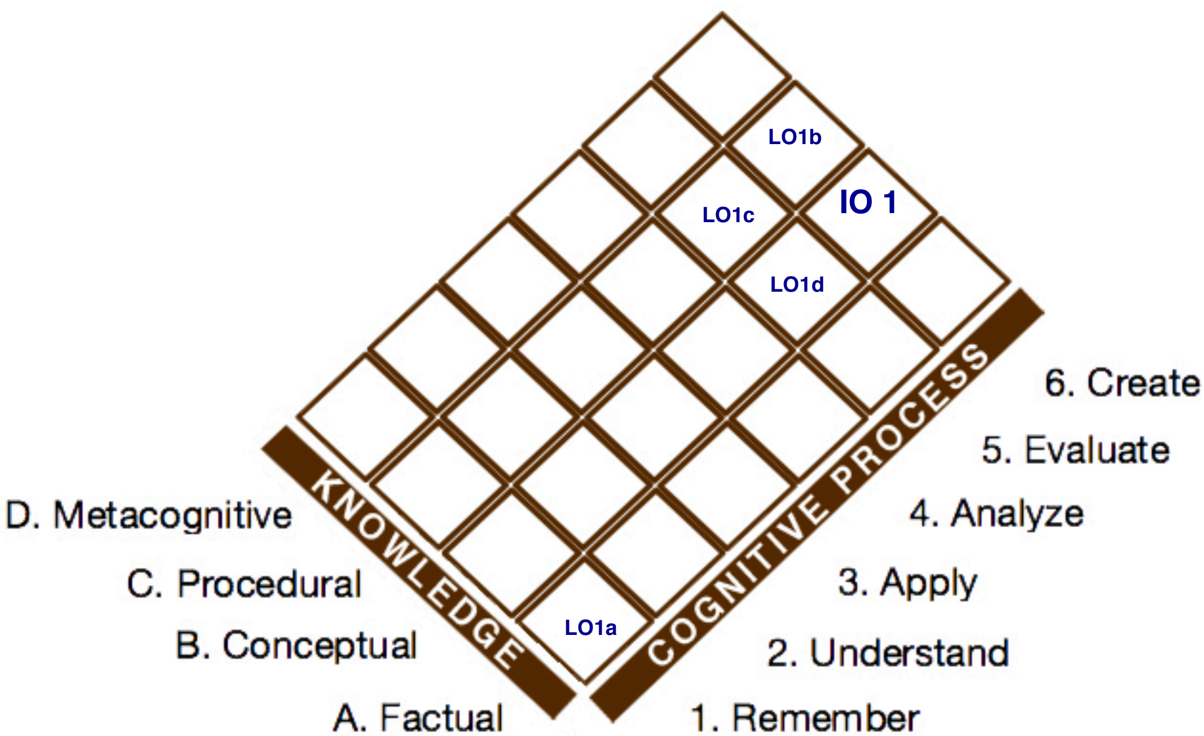
This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s). 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 apply the engineering design cycle to produce an engineering design that meets mission goals within constraints**.** (6.3; Bc)

LO1a. **to identify** limitations in an engineering design (1.1; Ab)
LO1b. **to generate** solutions by setting new requirements to improve engineering design (6.1; Cc)
LO1c. **to test** an engineering design (5.1; Cc)
LO1d **to evaluate** an engineering design (5.2; Bc)



(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 apply the engineering design cycle to produce an engineering design that meets mission goals within constraints.

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

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

LO1a: to identify limitations
1.1: to identify
Ab: knowledge of specific details and elements

LO1b: to generate proposed solutions
6.1: to generate
Cc: knowledge of criteria for determining when to use appropriate procedures

LO1c: to test an engineering design
5.1: to test
Cc: knowledge of criteria for determining when to use appropriate procedures

LO1d: to evaluate an engineering design
5.2: to judge with criteria
Bc: knowledge of theories, models, and structures