



Rover Races

High 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

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 OBJECTIVES

Students will be able

IO1: to apply the engineering design cycle to produce an engineering design that meets mission goals within constraints.



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?

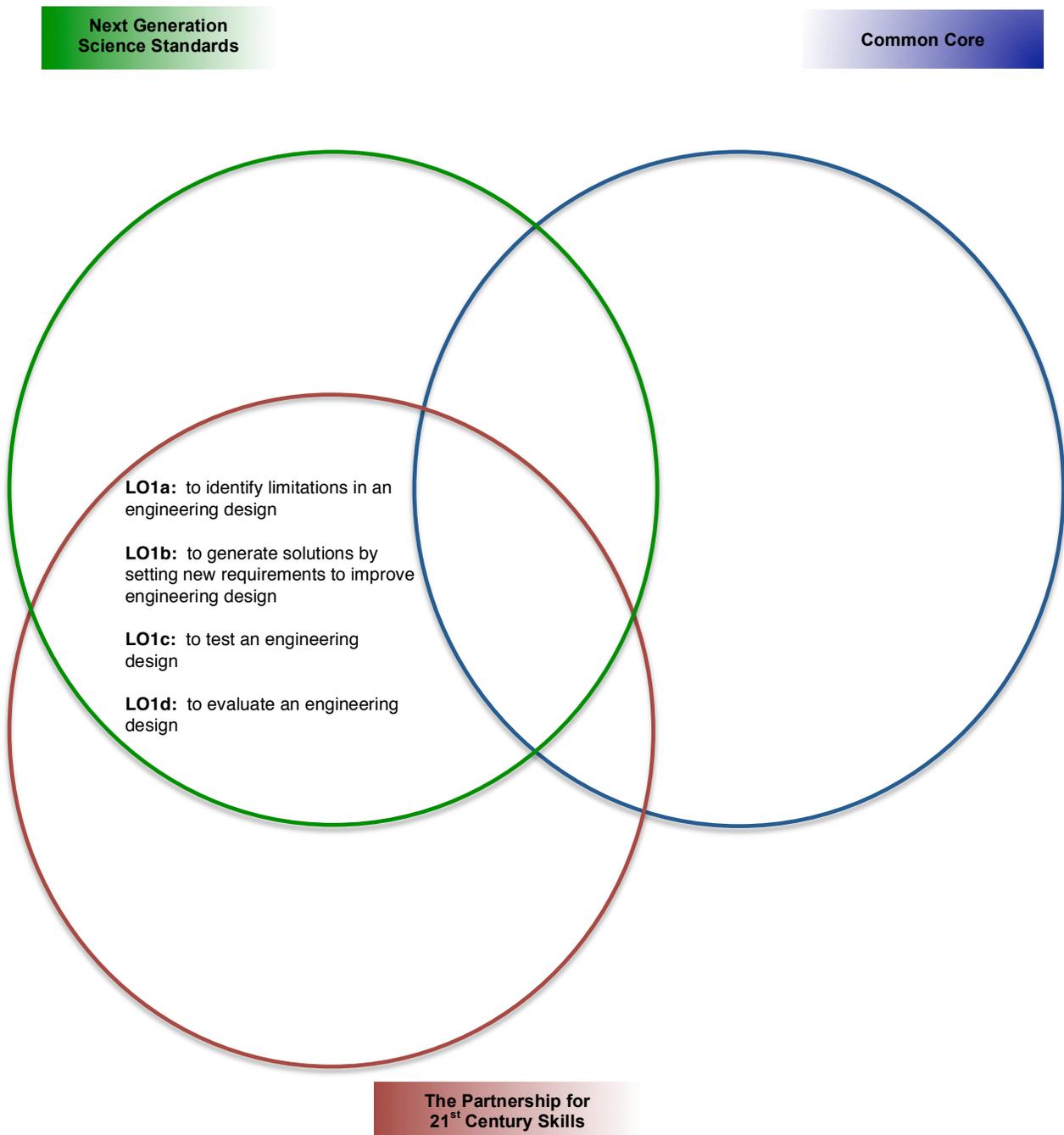
NRC ETS1.C: Optimizing the Design Solution

Instructional Objective <i>Students will be able</i>	Learning Outcomes <i>Students will demonstrate the measurable abilities</i>	Standards <i>Students will address</i>
<p>IO1:</p> <p>to apply the engineering design cycle to produce an engineering design that meets mission goals within constraints.</p>	<p>LO1a: to identify limitations in an engineering design</p> <p>LO1b: to generate solutions by setting new requirements to improve engineering design</p> <p>LO1c: to test an engineering design</p> <p>LO1d: to evaluate an engineering design</p>	<p>NGSS Practices:</p> <p>Asking Questions and Defining Problems</p> <p>Developing and Using Models</p> <p>Planning and Carrying out Investigations</p> <p>Analyzing and Interpreting Data</p> <p>Constructing Explanations and Designing Solutions</p> <p>Engaging in an Argument from Evidence</p> <p>NGSS Cross-Cutting Concept:</p> <p>Structure and Function</p> <p>Systems and System Models</p>



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)

This lesson supports the preparation of students toward achieving Performance Expectations using the Practices, Cross-Cutting Concepts and Disciplinary Core Ideas defined below: (HS-ETS1-2); (HS-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, or unexpected results, to clarify and/or seek additional information.
 - that arise from examining models or a theory, to clarify and/or seek additional information and relationships.
- Define a design problem that involves the development of a process or system with interacting components and criteria and constraints that may include social, technical, and/or environmental considerations.



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

- Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism or system in order to select or revise a model that best fits the evidence or design criteria.
- Design a test of a model to ascertain its reliability.
- 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.
- Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems.



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



- Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation's design to ensure variables are controlled.
- Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables.



Next Generation Science Standards (NGSS)

Practices: Analyzing and Interpreting Data

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- 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.
- Evaluate the impact of new data on a working explanation and/or model of a proposed process or system.
- Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success



Next Generation Science Standards (NGSS)

Practices: Constructing Explanations and Designing Solutions

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.



Next Generation Science Standards (NGSS)

Practices: Engaging in Argument from Evidence

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- 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.
- 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)

Cross-Cutting Concepts: Systems and System Models

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- 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. They can also design systems to do specific tasks.



Next Generation Science Standards (NGSS)

Cross-Cutting Concepts: Structure and Function

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students investigate systems by examining the properties of different materials, the structures of different components, and their interconnections to reveal the system's function and/or solve a problem. They infer the functions and properties of natural and designed objects and systems from their overall structure, the way their components are shaped and used, and the molecular substructures of their various materials.



Next Generation Science Standards (NGSS)

Disciplinary Core Idea: ETS1.B: Developing Possible Solutions

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Both physical models and computers can be used in various ways to aid in the engineering design process. Computers are useful for a variety of purposes, such as running simulations to test different ways of solving a problem or to see which one is most efficient or economical; and in making a persuasive presentation to a client about how a given design will meet his or her needs.



Next Generation Science Standards (NGSS)

Disciplinary Core Idea: ETS1.C: Optimizing the Design Solution

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Criteria may need to be broken down into simpler ones that can be approached systematically, and decisions about the priority of certain criteria over others (trade-offs) may be needed.



21st Century Skills

Critical Thinking

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students understand that scientific research and experimentation are guided by fundamental concepts, and that investigations are conducted for different reasons, such as exploring new phenomena, building on previous results, comparing different theories, and addressing problems facing society. (Grade 12 Benchmark)



21st Century Skills

Collaboration

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

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



21st Century Skills
Flexibility and Adaptability

(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students are able to revise their own scientific ideas and hypotheses based on new evidence or information. (Grade 12 Benchmark)

**(D) Teacher Resource. Rover Races Rubric (1 of 2)****Related Rubrics for the Assessment of Learning Outcomes Associated with the Above Standard(s):**

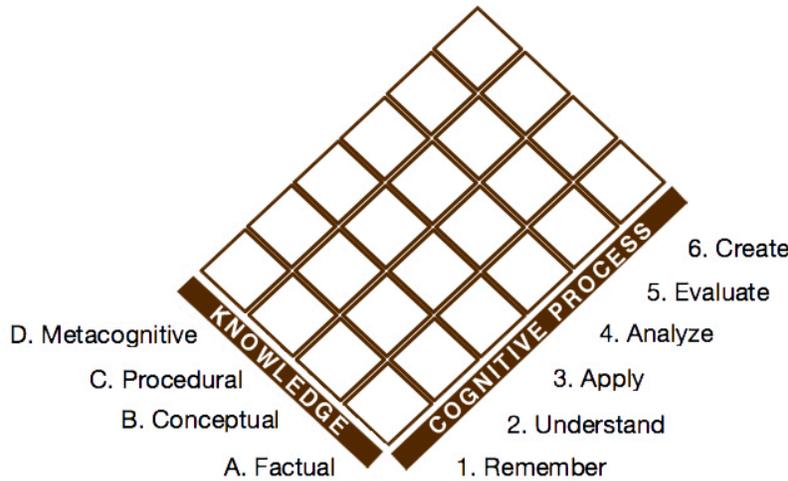
Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a: to identify limitations in an engineering design (rover command sequence)	Limitations identified are accurate, complete, and logical to the group and individual observations made during the process.	Limitations are accurate, and mostly complete 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.



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



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

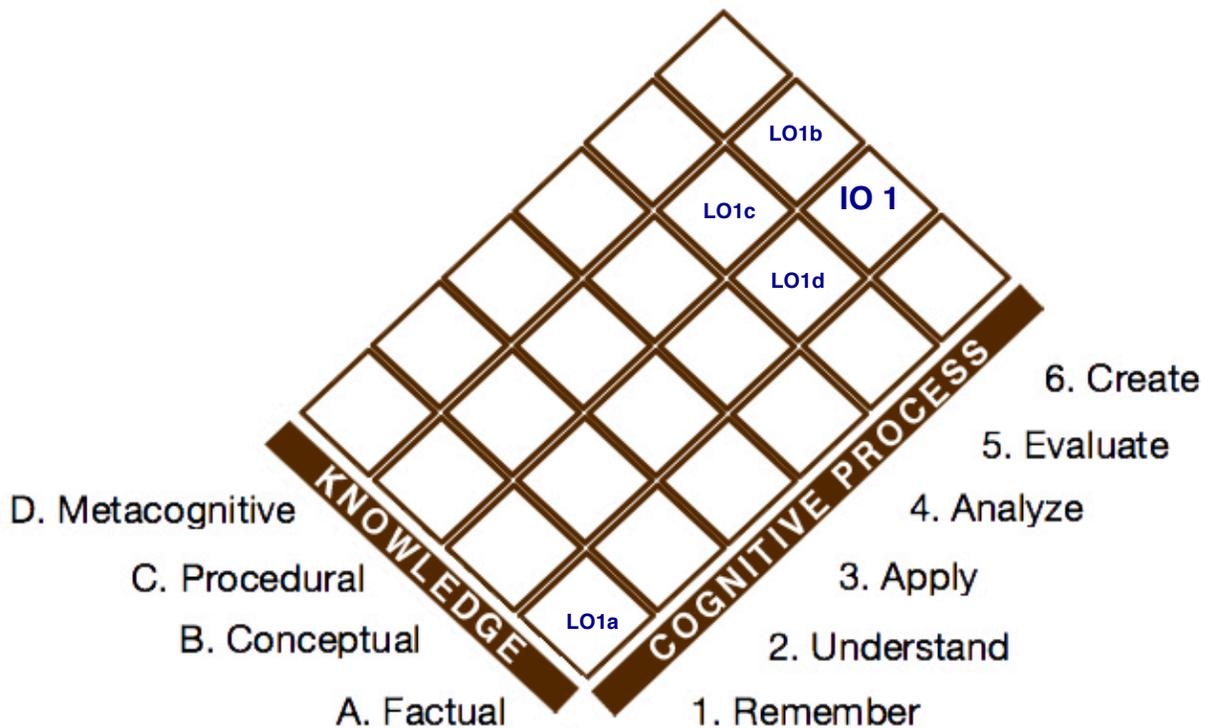
IO1: to apply the engineering design cycle to produce an engineering design that meets mission goals within constraints. (6.3; Bc)

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