Rover Races

3rd – 5th Grade 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

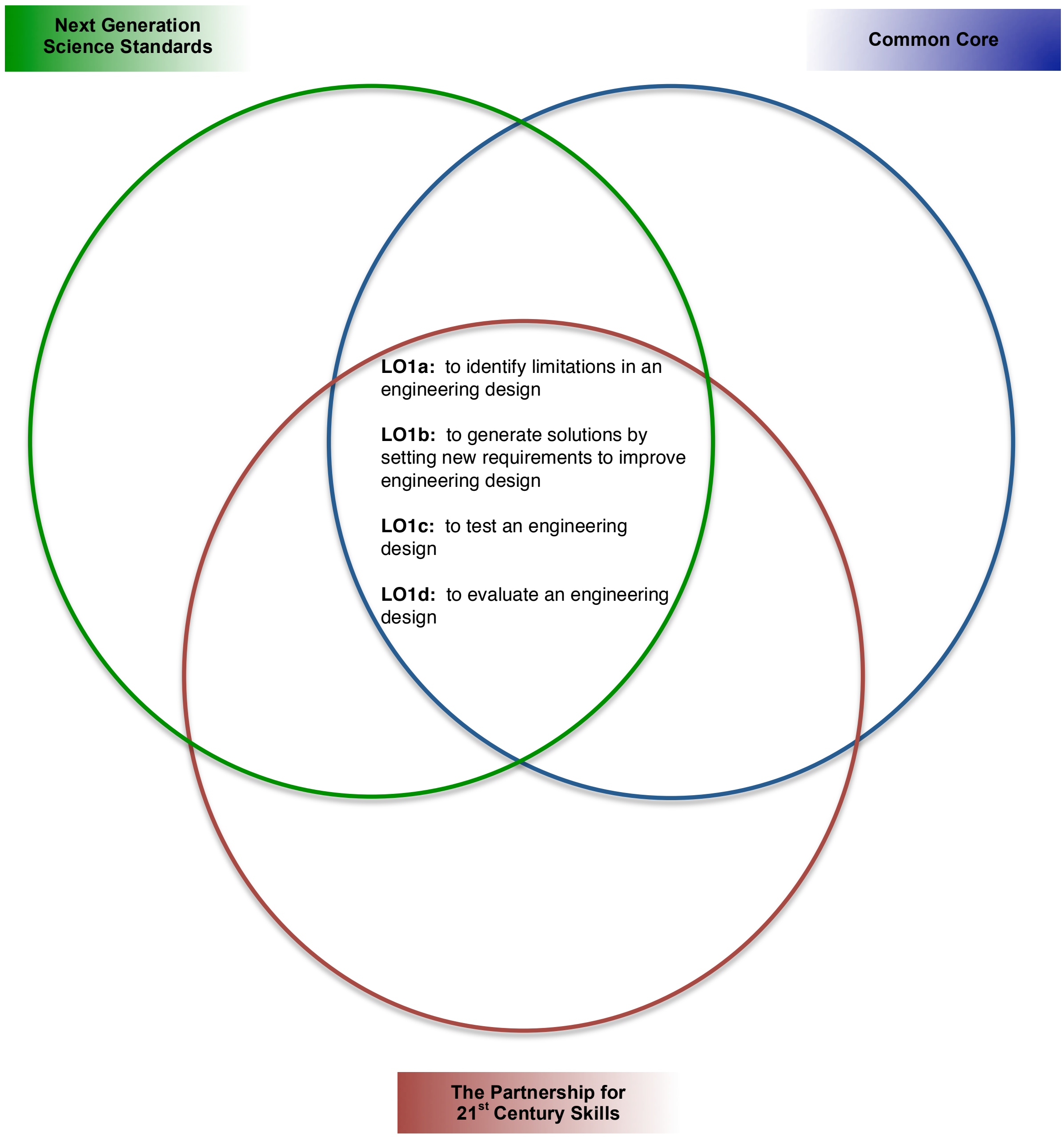
How can the various proposed design solutions be compared and improved?

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** **Using Mathematics and Computational Thinking** **Constructing Explanations and Designing Solutions** **Engaging in an Argument from Evidence** **NGSS Cross-Cutting Concept:** **Cause and Effect** **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: (3-5-ETS1-1); (3-5-ETS1-2); (3-5-ETS1-3)

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

- Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.

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

- Identify limitations of models.
- Collaboratively develop and/or revise a model based on evidence that shows the relationships among variables for frequent and regular occurring events.
- Develop a model using an analogy, example, or abstract representation to describe a scientific principle or design solution.
- Develop and/or use models to describe and/or predict phenomena.
- Develop a diagram or simple physical prototype to convey a proposed object, tool, or process.
- Use a model to test cause and effect relationships or interactions concerning the functioning of a natural or designed system.

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

- Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
- Make predictions about what would happen if a variable changes.
- Test two different models of the same proposed object, tool, or process to determine which better meets criteria for success.

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

- Analyze and interpret data to make sense of phenomena, using logical reasoning, mathematics, and/or computation.
- Compare and contrast data collected by different groups in order to discuss similarities and differences in their findings.
- Analyze data to refine a problem statement or the design of a proposed object, tool, or process.
- Use data to evaluate and refine design solutions.

Next Generation Science Standards (NGSS)
Practices: Using Mathematics and Computational Thinking
(Learning Outcomes Addressed: LO1c)

- Describe, measure, estimate, and/or graph quantities (e.g., area, volume, weight, time) to address scientific and engineering questions and problems.

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

- Construct an explanation of observed relationships (e.g., the distribution of plants in the back yard).
- Use evidence (e.g., measurements, observations, patterns) to construct or support an explanation or design a solution to a problem.
- Identify the evidence that supports particular points in an explanation.
- Generate and compare multiple solutions to a problem based on how well they meet the criteria and constraints of the design solution.

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

- Respectfully provide and receive critiques from peers about a proposed procedure, explanation, or model by citing relevant evidence and posing specific questions.
- Construct and/or support an argument with evidence, data, and/or a model.
- Use data to evaluate claims about cause and effect.
- Make a claim about the merit of a solution to a problem by citing relevant evidence about how it meets the criteria and constraints of the problem.

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

- Students routinely identify and test causal relationships and use these relationships to explain change. They understand events that occur together with regularity might or might not signify a cause and effect relationship.

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

- Students understand that a system is a group of related parts that make up a whole and can carry out functions its individual parts cannot. They can also describe a system in terms of its components and their interactions.

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

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account.

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

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions.
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs.
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved.

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

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints.

Common Core State Standards
Speaking and Listening Standards: Comprehension and Collaboration
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 3 topics and texts, building on others' ideas and expressing their own clearly. (Grade 3)
    - Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
    - Follow agreed-upon rules for discussions (e.g., gaining the floor in respectful ways, listening to others with care, speaking one at a time about the topics and texts under discussion).
    - Ask questions to check understanding of information presented, stay on topic, and link their comments to the remarks of others.
    - Explain their own ideas and understanding in light of the discussion.
- Ask and answer questions about information from a speaker, offering appropriate elaboration and detail. (Grade 3)

- Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 4 topics and texts, building on others' ideas and expressing their own clearly. (Grade 4)
    - Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
    - Follow agreed-upon rules for discussions and carry out assigned roles.
    - Pose and respond to specific questions to clarify or follow up on information, and make comments that contribute to the discussion and link to the remarks of others.
    - Review the key ideas expressed and explain their own ideas and understanding in light of the discussion.
- Identify the reasons and evidence a speaker provides to support particular points. (Grade 4)

- Engage effectively in a range of collaborative discussions (one-on-one, in groups, and teacher-led) with diverse partners on grade 5 topics and texts, building on others' ideas and expressing their own clearly. (Grade 5)
  - Come to discussions prepared, having read or studied required material; explicitly draw on that preparation and other information known about the topic to explore ideas under discussion.
  - Follow agreed-upon rules for discussions and carry out assigned roles.
  - Pose and respond to specific questions by making comments that contribute to the discussion and elaborate on the remarks of others.
  - Review the key ideas expressed and draw conclusions in light of information and knowledge gained from the discussions.
- Summarize the points a speaker makes and explain how each claim is supported by reasons and evidence. (Grade 5)

Common Core State Standards
Speaking and Listening Standards: Presentation of Knowledge and Ideas
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Report on a topic or text, tell a story, or recount an experience with appropriate facts and relevant, descriptive details, speaking clearly at an understandable pace. (Grade 3)
- Speak in complete sentences when appropriate to task and situation in order to provide requested detail or clarification. (Grade 3)

- Report on a topic or text, tell a story, or recount an experience in an organized manner, using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (Grade 4) Differentiate between contexts that call for formal
- English (e.g., presenting ideas) and situations where informal discourse is appropriate (e.g., small-group discussion); use formal English when appropriate to task and situation. (See grade 4 Language standards 1 on pages 28 and 29 for specific expectations.) (Grade 4)

- Report on a topic or text or present an opinion, sequencing ideas logically and using appropriate facts and relevant, descriptive details to support main ideas or themes; speak clearly at an understandable pace. (Grade 5)
- Adapt speech to a variety of contexts and tasks, using formal English when appropriate to task and situation. (See grade 5 Language standards 1 and 3 on pages 28 and 29 for specific expectations.) (Grade 5)

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

- Students construct their own scientific understanding and develop their scientific process skills by asking scientific questions, designing and conducting investigations, constructing explanations from their observations, and discussing their explanations with others. (4th Grade Benchmark)

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

- Students understand that models are simplified representations of real objects and processes, and that models serve as a means to communicate ideas and knowledge about how things work. (Grade 4 Benchmark)

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

- Students work collaboratively with others, both in small and large groups, in their science classroom. (Grade 4 Benchmark)

- 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
Flexibility and Adaptability
(Learning Outcomes Addressed: LO1a, LO1b, LO1c, LO1d)

- Students can provide illustrative examples of science as an ongoing process that includes expanding, revising, and sometimes discarding theories based on new evidence, and that our understanding of a topic can change as more research is completed. (4th Grade 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. (4th Grade Benchmark)

(D) Teacher Resource. Rover Races Rubric (2 of 3)

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 3)

Partnership for 21st Century Skills

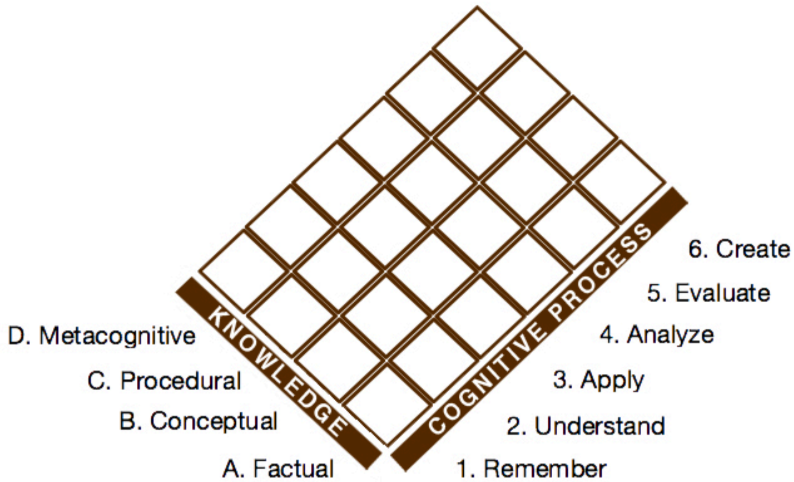
	Expert	Proficient	Intermediate	Beginner
Effectiveness of collaboration with team members and class.	Extremely Interested in collaborating in the simulation. Actively provides solutions to problems, listens to suggestions from others, attempts to refine them, monitors group progress, and attempts to ensure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

(L) Teacher Resource. Rover Races Rubric (3 of 3)

Common Core – ELA

	Expert	Proficient	Intermediate	Beginner
Effective Demonstration of Comprehension and Collaboration	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.	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.	Interested in collaborative discussion. Asks questions. Articulates own ideas related to the discussion.	Interested in collaboration with peers.
Effective Presentation of Knowledge and Ideas	Includes accurate drawings of concepts, speaks audibly, clearly and in complete sentences, and writes ideas in complete sentences.	Includes accurate drawings of concepts, speaks audibly, and in complete sentences, writes most ideas in complete sentences.	Includes drawings of concepts, speaks audibly, writes most ideas in complete sentences.	Includes drawings of concepts and speaks when spoken to.

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



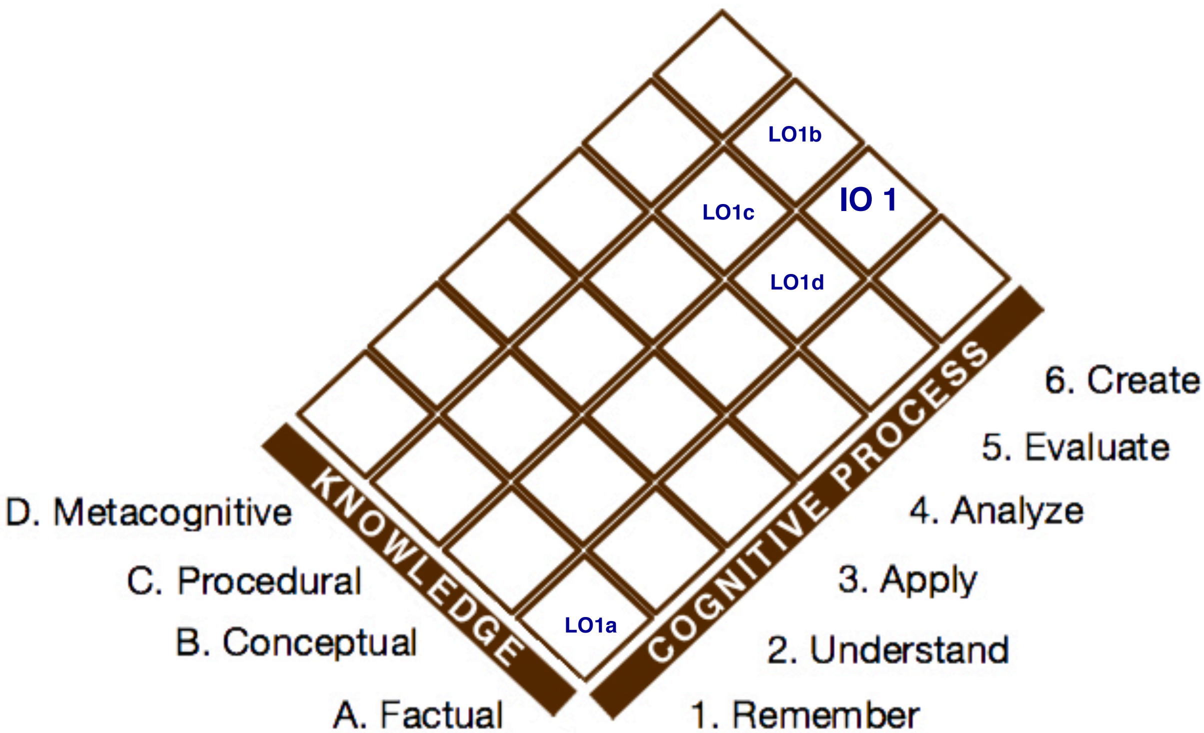
This lesson adapts Anderson and Krathwohl's (2001) taxonomy, which has two domains: Knowledge and Cognitive Process, each with types and subtypes (listed below). Verbs for objectives and outcomes in this lesson align with the suggested knowledge and cognitive process area and are mapped on the next page(s).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