A Microsoft/NASA Collaboration

Lesson 2

Programming a Rover

Grades: 5-8 Prep Time: ~15-60 Minutes Lesson Time: 2 Hours

WHAT STUDENTS DO: Determine the Most Effective Set of Commands to Program a Rover to Move Autonomously Across Terrain To Collect Scientific Data.

NASA's Mars rover Curiosity might be the size of a small car, but it's not driven like one! Instead, the rover relies on a set of computer commands from scientists and engineers on Earth, who plan its route to a place where they think they can make the most discoveries. The mission team tells the rover where to go, when to turn, and how to avoid hazards along its way by uplinking these complex plans through large communications antennas on Earth that send these daily instructions to the rover on Mars. They also tell the rover when and for how long to use its onboard science tools to scan and analyze rocks and soils and other environmental elements that may hold clues to a key science question: Was Mars ever a habitat (a place able to support life)?

In this lesson, students will move from controlling the rover using a joystick to more realistically writing algorithms that will cause the rover to move autonomously. As the rover explores Martian terrain, it will earn points for examining different types of rocks. Students will learn about both Earth Science concepts and the rocks' value in answering the question of Mars' habitability. Some terrain will slow down the rover, so students have to plan their route accordingly. Students will program how the rover will move and act autonomously and run several trials, evaluating and refining their rover's programming to maximize the amount of points they can earn before their limited supply of power runs out. This level introduces a power constraint; different actions will cause the rover to lose set amounts of power. Building in standards related to principles of technological design, the success of their search depends on their ability to plan, test, and revise their algorithm to score the most points using the limited amount of power.

NRC CORE & COMPONENT QUESTIONS	INSTRUCTIONAL OBJECTIVES
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* **How Can the Various Proposed Design Solutions be Compared and Improved?** *NRC ETS1.C: Optimizing the Design Solution* **WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?** *NRC Core Question: ESS1: Earth's Place in the Universe* **How do people reconstruct and date events in Earth's planetary history?** *NRC ESS1.C: The History of the Planet Earth* **HOW AND WHY IS EARTH CONSTANTLY CHANGING?** *NRC Core Question: ESS2: Earth's Systems* **How do the properties and movements of water shape Earth's surface and affect its systems?** *NRC ESS2.C: The Role of Water in Earth's Surface Processes*	*Students will be able* **IO1: to design** an algorithm that reflects Earth science-related criteria and engineering constraints. **IO2: to execute** an algorithm that reflects Earth science-related criteria and engineering constraints.

1.0 About This Activity

This activity is a collaboration between NASA and Microsoft Studios to teach students about the Mars Exploration Program by creating interactive worlds using a 3D programming environment called the *Kodu Game Lab*. The curriculum integrates the *NRC Conceptual Framework for New K-12 Science Education Standards*, the *P21 21st Century Learning Skills*, and the *CSTA K-12 Computer Science Standards* into lessons that will excite students about STEM (Science, Technology, Engineering, and Mathematics). Students will create worlds that reflect the Mars terrain and program a virtual model of the Mars rover Curiosity as it searches for habitats on Mars. As students learn about the different landforms on the surface of Mars, the different rock types and how they may hold signs of any possible microbial life on Mars, they will also learn about robotics and how to create algorithms using code. *Kodu Game Lab* makes programming fun and approachable for novices through a tile-based user interface, engaging characters, and simple 3D terrain editing.

These Kodu lessons leverage *A Taxonomy for Learning, Teaching, and Assessing* by Anderson and Krathwohl (2001) (see *Section 4* and the *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.** 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.

- **Explore.** The Explore step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata.
- **Explain.** In Explain, students communicate what they have learned, illustrating initial conceptual change.
- **Elaborate.** 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.
- **Evaluate.** 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 Kodu instructional series. The 5E stages can be cyclical and iterative.

2.0 Materials

Required Materials

Please download:

- *Kodu Game Lab* at: www.kodugamelab.com
- System requirements:
  - Supported operating systems: Windows 7, Windows Vista, Windows XP
  - A graphics card that supports DirectX 9.0c and Shader Model 2.0 or higher is required.
  - .NET Framework 3.5 or higher is required.
  - XNA Framework 3.1 Redistributable is required.

Please Print:

From the *Student Guide*:

(A) Kodu Path Tool	- 1 per student
(B) Kodu When-Do Statements	- 1 per student
(C) Programming a Rover Evaluation	- 1 per student

From the *Teacher Guide*:

(D) Programming a Rover Rubric

(E) Placement of Instructional Objective and Learning Outcomes in Taxonomy

Optional Materials

Xbox 360 Wired Controller

4.0 Vocabulary

Algorithm	A series of steps to perform a task.
Analyze	To consider data and results to look for patterns and to compare possible solutions.
Autonomous	Able to act without outside guidance.
Beam	To emit light; in Kodu, this function activates a laser to analyze an object (the “B” key on a keyboard or the “B” button on a controller).
Conditional statement	A logical statement resulting from the connection of a true or false event and its resulting consequence.
Constraints	Limitations or restrictions.
Criteria	A standard on which a judgment is based.
Evaluate	To check the scientific validity or soundness.
Inspect	To examine closely. In Kodu, for example: one function activates a drill to inspect a rock (the “X” key on a keyboard or the “X” button on a controller).
Organics	Carbon-based molecules that are the chemical building blocks of life as we know it.
Node	Connection point.
Phyllosilicates	A special type of clay (a sedimentary rock) that can preserve signs of organics.
Program	Coded instructions to perform a task.
Robotics	The use of machines to perform manual tasks.
Rover	A remotely-controlled vehicle that roams over terrain, taking photographs and gathering data about the terrain’s surface.
Scan	To examine an area or object. In Kodu, this function reveals the type of rocks that are within a specific range from the rover (the “A” key on a keyboard or the “A” button on a controller).
Sedimentary Rock	A type of rock formed by the accumulation of sediments on the surface (e.g., volcanic ash) or in bodies of water.

Syntax Error	An error in the sequence used to compose an instruction given to a computer.
Tele-operate	To operate remotely.
Trade-off	An exchange of one set of criteria for another.
Traverse	To move across.
Uplink Command	Directions sent through antennas on Earth and received by antennas on a spacecraft or rover.
Volcanic Rock	A rock formed from magma that erupted from a volcano and cooled on the surface (also igneous rock, and often basalt).

5.0 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 the 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 the *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 aligned with, Anderson and Krathwohl's (2001) taxonomy of knowledge and cognitive process types. For convenience, a quick view is included on the next page:

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

How Can the Various Proposed Design Solutions be Compared and Improved?
NRC ETS1.C: Optimizing the Design Solution

WHAT IS THE UNIVERSE, AND WHAT IS EARTH'S PLACE IN IT?
NRC Core Question: ESS1: Earth's Place in the Universe

How do people reconstruct and date events in Earth's planetary history?
NRC ESS1.C: The History of the Planet Earth

HOW AND WHY IS EARTH CONSTANTLY CHANGING?
NRC Core Question: ESS2: Earth's Systems

How do the properties and movements of water shape Earth's surface and affect its systems?
NRC ESS2.C: The Role of Water in Earth's Surface Processes

Instructional Objective *Students will be able*	**Learning Outcomes** *Students will demonstrate the measurable abilities*	**Standards** *Students will address*	
IO1: **To design** an algorithm that reflects Earth science-related criteria and engineering constraints **IO2:** **To execute** an algorithm that reflects Earth science-related criteria and engineering constraints	**LO1a. To translate a natural language procedure into a programming language algorithm.** **LO1b. To differentiate the visual characteristics of volcanic and sedimentary rocks and their scientific significance.** **LO2a. To test, evaluate, and refine an algorithm.** **LO2b. To monitor resource usage while achieving mission goals.**	**NSES: UNIFYING CONCEPTS & PROCESSES:** **K-12: Evidence, models, and explanations** **NSES (D): EARTH AND SPACE SCIENCE:** **Structure of the Earth System** **Grades 5-8:** D1c, D1d, D1e. **NSES (E): SCIENCE & TECHNOLOGY** **Abilities of Technological Design** **Design a Solution or a Product** **Grades 5-8:** E1b	***Rubrics in Teacher Guide***

This activity also aligns with:

NRC SCIENCE & ENGINEERING PRACTICES

1) Asking questions and defining problems
2) Developing and using models
3) Planning and carrying out investigations
4) Analyzing & interpreting data
5) Using mathematical and computational thinking
6) Constructing explanations and designing solutions
7) Engaging in argument from evidence.

NRC SCIENCE & ENGINEERING CROSSCUTTING CONCEPTS

1) Patterns
2) Cause and effect
3) Scale, proportion, and quantity
4) Systems and system models
5) Energy and Matter: flows, cycles, and conservation
6) Stability and change

CSTA K-12 Computer Science Standards

L2.CT.1 Use the basic steps in algorithmic problem solving to design solutions (e.g., problem statement and exploration, examination of sample instances, design, implementing a solution, testing, evaluation).

L2.CT.3 Define an algorithm as a sequence of instructions that can be processed by a computer.

L2.CT.6 Describe and analyze a sequence of instructions being followed.

L2.CL.3 Collaborate with peers, experts, and others using collaborative practices such as pair programming, working in project teams, and participating in group active learning activities.

L2.CPP.4 Demonstrate an understanding of algorithms and their practical application.

L2.CPP.5 Implement problem solutions using a programming language, including: looping behavior, conditional statements, logic, expressions, variables, and functions.

L2.CPP.8 Demonstrate dispositions amenable to open-ended problem solving and programming (e.g., comfort with complexity, persistence, brainstorming, adaptability, patience, propensity to tinker, creativity, accepting challenge).

L2.CPP.9 Collect and analyze data that is output from multiple runs of a computer program.

21ST CENTURY SKILLS

- Creativity and Innovation
- Critical Thinking and Problem Solving
- Communication

- Collaboration

5.0 Procedure

PREPARATION (~15-60 minutes)

Installing and Learning the Basics of Kodu

A. Download and install *Kodu Game Lab* from www.kodugamelab.com

B. Pair students into groups of two. Create mixed-ability pairs based on familiarity with game development, computer programming, and use of the Xbox 360 controller (if it's being used).

C. Students do not require any previous Kodu experience, but you may choose to have them complete the basic introductory tutorials at www.kodugamelab.com/About

STEP 1: ENGAGE (~20 minutes)

A Rover Explores the Surface of Mars

A. Show a picture of a rover on Mars (such as the artist's concept available at www.mars.jpl.nasa.gov/msl/multimedia/images/?ImageID=3504) and discuss relevant vocabulary. To elicit prior knowledge of other robotic vehicles, ask students to name other robotic vehicles, such as robotic drones used in surveillance or robotic submarine probes used to explore the deep ocean floor.

B. Introduce a puzzle: tell students that Mars is hundreds of millions of miles away from Earth. It takes about 8 – 20 minutes for a signal (message) to get to a rover on Mars (depending on how far away the planets are from each other in their orbits around the sun), and the same amount of time for any message to be returned. Also, no external camera systems are around on the surface of Mars to watch the rover as it moves (the only cameras are on Curiosity itself). Rover drivers on Earth must carefully plan the rover's path, making sure it doesn't get into trouble (go over cliffs, get stuck in sand traps, run into a rock, etc.). How can they drive the rover safely when they can't see it and when it takes so long to send the rover a command and then receive a message back that it was successful?

C. Have students brainstorm how a robotic vehicle like a Mars rover might be controlled when no human is there to drive it.

D. To learn more about the Mars Science Laboratory, view an animation and read about how the rover, Curiosity, will utilize advances in autonomous navigation: www.mars.jpl.nasa.gov/msl/mission/technology/insituexploration/planetarymobility/

✓ **Teacher Tip**

To demonstrate the importance of programming a rover through a series of commands and working with a series of constraints or limitations, students can complete the Rover Races activity provided at http://marsed.asu.edu/lesson_plans/rover_races.

STEP 2: EXPLORE (~20 minutes)

Rocks Have Different Scientific Significance in the Search for Habitats on Mars

Pair Programming

A. Students will work with a partner, and the two will share a single computer, utilizing a method called pair programming.

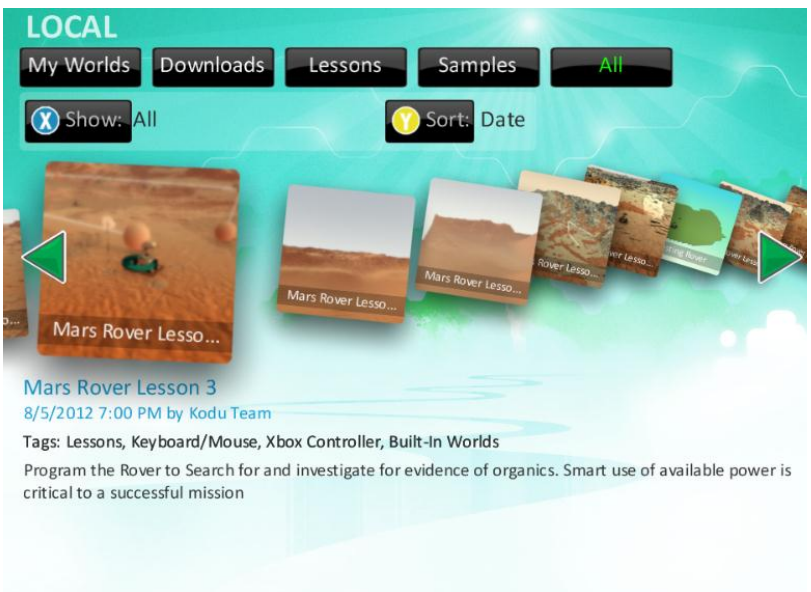
B. One student will act as the "driver." The driver is the only person to touch the keyboard and mouse or controller.

C. The other student is the "navigator." The navigator gives advice, instructs, and evaluates the pair's progress.

D. The two students should switch roles every 5 to 10 minutes throughout the class period to allow both of them to perform the different roles.

Explore the World

A. Have students open the *Programming a Rover* world in Kodu.



B. Describe the game.
   a. Explain that scientists and engineers want to make as many discoveries as possible as they explore the surface of Mars. They command the rover to move to places that are scientifically interesting so that they can study those places. Explain that rocks are important to scientific discovery because they hold clues to the environment in which they formed.
   b. The rover is tasked with examining the rocks on the surface of Mars' terrain. When the rover scans rock on Mars, it reveals the rock's type, either sedimentary

or volcanic. Beaming a rock activates the laser spectrometer which is used to analyze the rock. Inspecting a rock activates a drill that will gather a sample of the rock for the rover's onboard analysis systems.

c. The scoring system (upper right corner of the screen):
    i. The white (top) number represents the Scientific Discovery Points.
    ii. The green (middle) number reflects how many times the Inspect Tool can be used.
    iii. The purple (bottom) number reflects the amount of power the rover has remaining. Students must keep track of their power usage as every action uses a specific amount of the rover's limited power supply.

C. When they start the world, the rover does not move. Before students learn how to program the rover, they will explore the world and plan the algorithm they will use to program the rover's path.

D. Have students press the Escape key on the keyboard to stop the game and reveal the Kodu tool menu.

E. Show students how to manipulate the camera so they can observe the entire world.
    a. Select the Move Camera tool (it looks like a hand).
    b. Follow the instructions in the top left of the screen to manipulate the camera. Zoom out to see more of the world.

    c. Have students take turns examining the terrain by controlling the camera. Ask them to share what they have observed. They should notice the landforms and rocks that make up Mars' terrain.

F. Ask: What is a rock? What is a mineral?
    a. A mineral is a naturally occurring solid with a specific chemical composition.
    b. A rock is a naturally occurring solid composed of one or more minerals.

G. Explain that there are two basic rock types typically found on the surface of Mars: volcanic rocks and sedimentary rocks. (Metamorphic rocks are possible, but have not been found in places rovers have explored so far.)

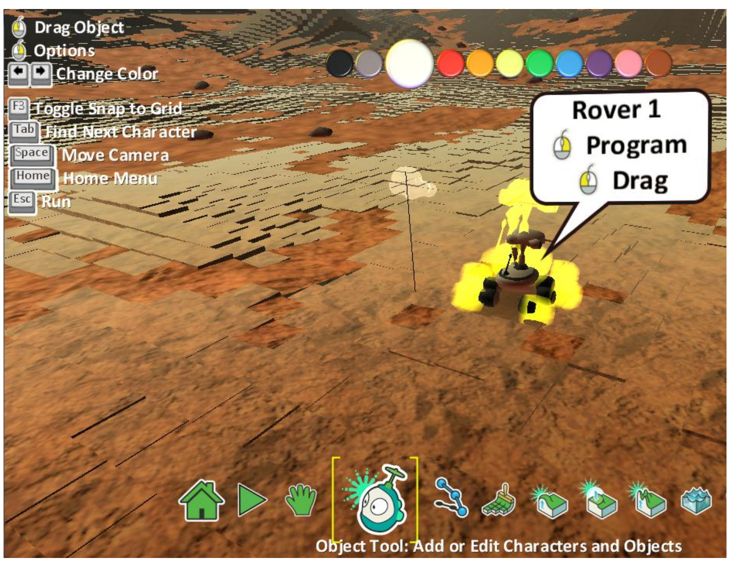
H. As students explore the world, ask them to hypothesize where sedimentary volcanic rocks might be found. Have them plan the path the rover will take to visit areas of interest in the world.

STEP 3: EXPLAIN (~20 minutes)

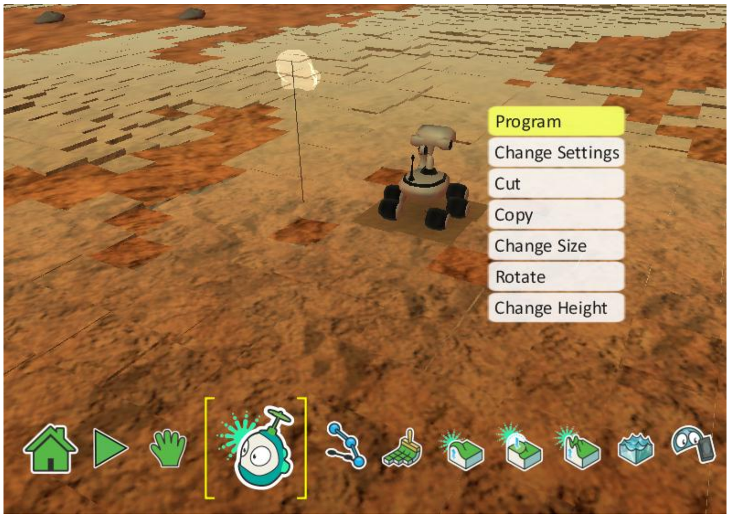
Goal, Criteria, and Constraints

A. Explain that the goal of the game is to determine the best path to program the rover to search and inspect the rocks to collect the most Scientific Discovery Points. Real rovers have a limited supply of power. The better the path the rover follows, the higher the score. Define the criteria:
   a. Inspect sedimentary and volcanic rocks.
   b. Beam sedimentary and volcanic rocks.
   c. Scan sedimentary and volcanic rocks.

B. To compare how many points each action awards and how much power each action uses, have students examine the rover's code.
   a. To reveal the Kodu tool menu (if not already there), press the Escape key.
   b. Select the **Object Tool** and hover over the rover.



   c. Right-click the rover and select **Program**.



d. Students should see the first page of code governing how the rover scores points and subtracts power. Press the **TAB** key or **Shift+TAB** on the keyboard or the left and right triggers on the controller to navigate the different pages of code.
e. Ask them to focus on the statements that reference purple (bottom) and white (top) scores. They should compare all of the rover's actions based on how many points they award and how much energy they use.

C. Define the constraints.
   a. First, discuss with your students the following real-world example: On Mars, mission teams must work within constraints such as:
      i. How much power is available
      ii. How much power each science tool needs to perform an action
      iii. How many times a scanning tool can be used
      iv. How much memory a robot's computer has to store results
      v. Time limits (usually related to when an orbiter flies overhead to help transmit messages back to Earth or what the rover can do during a day)
   b. In this experience, students can consider two constraints:
      i. Limited uses of Inspect action
      ii. Limited power supply

D. The sedimentary rocks will score more points when they are inspected because they are of greater scientific value in the search for habitats on Mars. Some sedimentary rocks are more important than others. Some can contain minerals that form in water (e.g., hematite), which tell scientists the environment had water long ago. Water is necessary to life as we know it. Some sedimentary rocks can have organics, the chemical building blocks of life. Sedimentary rocks called phyllosilicates (clay minerals) form under wet, warm, non-acidic conditions that can support life. On Mars, phyllosilicates are also of great interest because they can preserve signs of organics over millions of years, giving scientists even greater clues about when in Mars' history it might have had all of the right environmental conditions necessary for life.

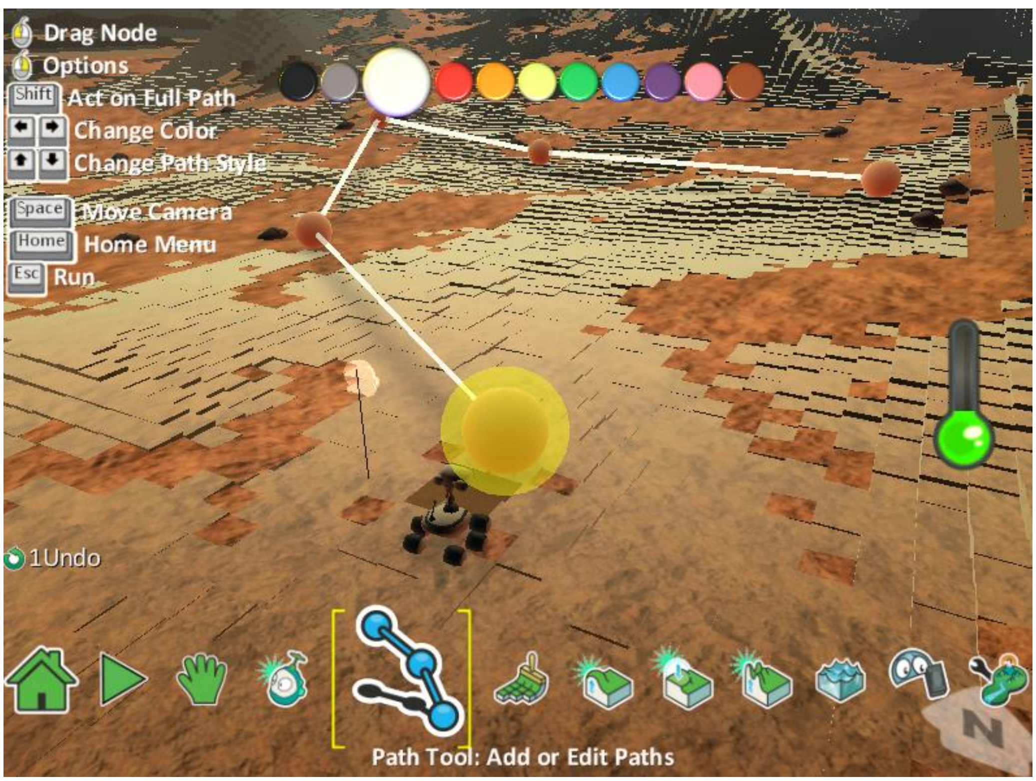
STEP 4: ELABORATE (~45 minutes)

Program the Rover to Move Along a Path

A. Explain to students that rather than being commanded in real-time due to the delay it takes for a command to reach Mars, rovers are controlled through a series of instructions in a program. The series of instructions, also known as an algorithm, controls all of the actions that the rover performs.

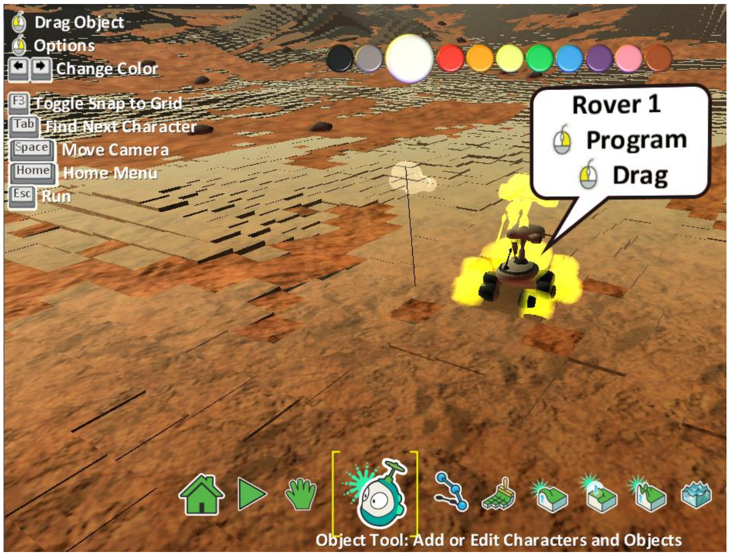
B. Right now the rover does not move, but it is preprogrammed to perform certain actions when it sees the different types of rocks, as students saw when they examined the rover's code. The students' goal is to add code to the rover's program so that it will follow a designated path to visit the different rocks. Once a rover gets near a rock, its preprogrammed instructions will perform the necessary actions.

C. The first thing to do is to designate a path. Have students refer to the *(A) How to Use the Kodu Path Tool* worksheet.
   a. To reveal the Kodu tool menu (if not already there), press the Escape key.
   b. Show students how to use the **Path Tool** to create the rover's path. A path is marked by a sequence of nodes. Select the Path tool and click on a location to place a path node.

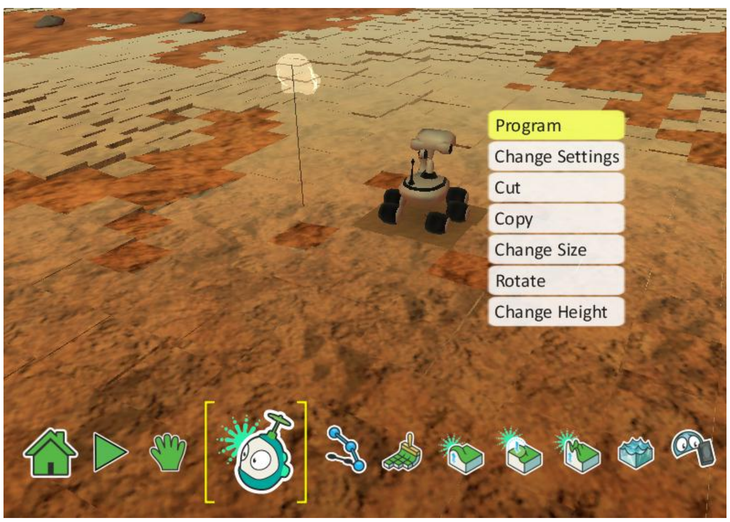


   c. Continue clicking to lay out the rover's path. Press Escape when the path is complete. As students lay down the nodes in the path, they should avoid the darker areas, which represent sand and which will slow the rover down.

D. Once the path is laid out, students can program the rover to follow the path. Display the When-Do statements that control the rover.
   a. To reveal the Kodu tool menu (if not already there), press the Escape key.
   b. Select the **Object Tool** and hover over the rover.

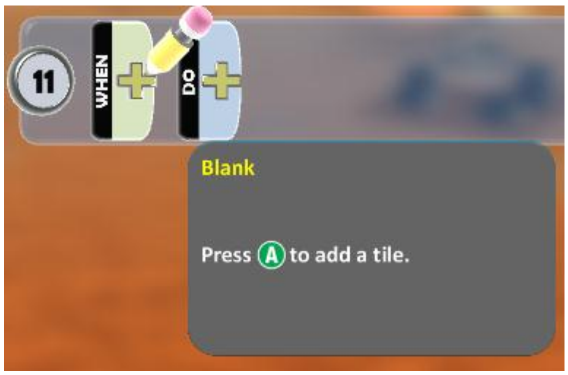


   c. Right-click the rover and select **Program**.

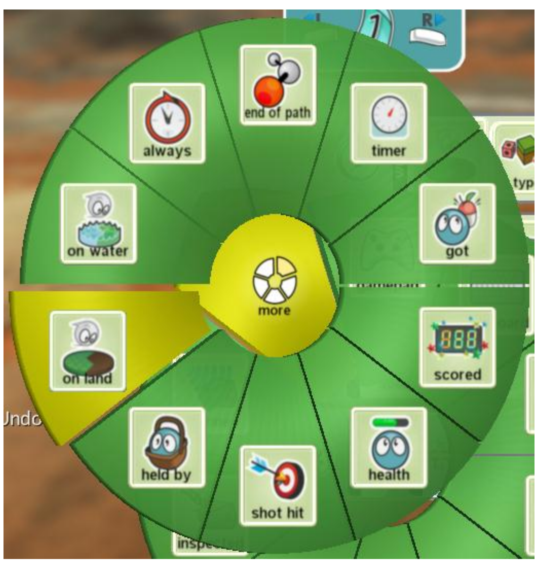


E. Students should see the pre-existing code. Have students refer to the *(B) Kodu When-Do Statements* worksheet.
   a. Before explaining how to program the rover to follow the path, ask students to use a single statement to describe what they want the rover to do. Remind the students that there are two possibilities for rover speed depending on what type of terrain it is on.
   b. They should create the following When-Do statements for lines 11 and 12.

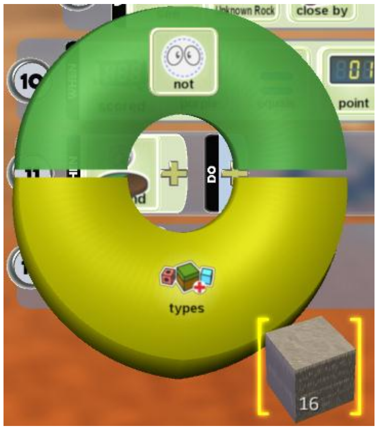
c. First, click on the plus sign in the **When** section of statement 11 and select **more**.



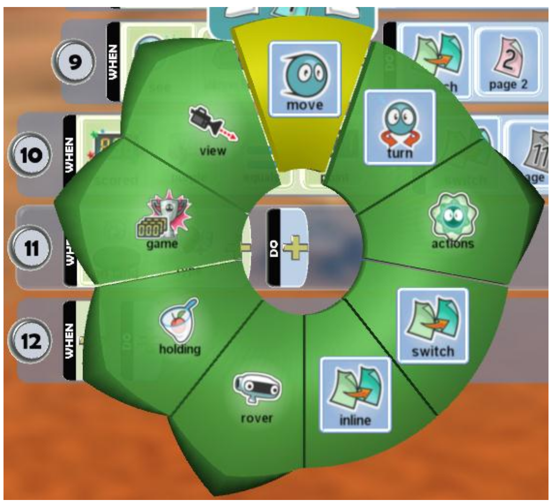
d. Second, click the **on land** tile.



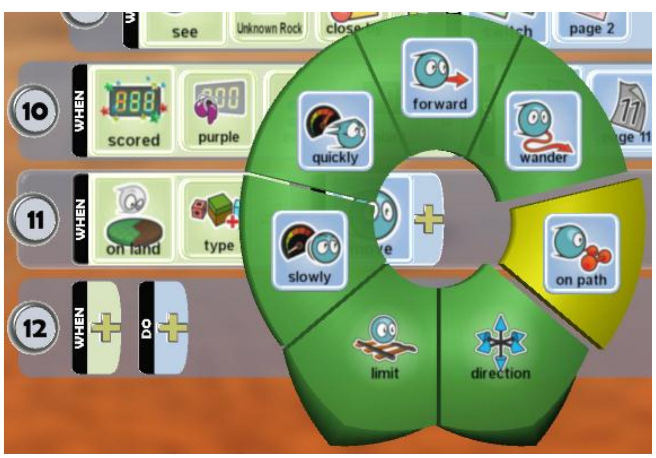
e. Third, click the plus sign next to the **on land** tile and choose **types** and then **material 16**.



f. Next, click the plus sign in the **do** section and choose the **move** tile.



g. Then click on the plus sign next to the **move** tile and choose the **on path** tile.



h. When the rover is on **land type 16**, it should move on the path laid out, but slowly, simulating terrain that slows down the rover. Students should click on the plus sign next to the **on path** tile and select **slowly** three times.

i. Have them follow the same directions to program the rover to move on the path at normal speed when **not** on **land type 16**, as seen below:

j. Kodu's tile-based language allows students to experiment with the code without being frustrated by error messages resulting from syntax errors. A syntax error occurs when a user writes an instruction that the program cannot understand.

F. As the students experiment with the rover's path and code, they should observe how the score is calculated and the significance of the different rocks. They should also see how the rover's actions use different amounts of the limited power supply.

G. Students should iteratively edit the path and run the world to score the most Scientific Discovery Points with the limited power supply. When the power supply gets too low, the rover is preprogrammed take pictures of its surroundings for further planning.

STEP 5: EVALUATE (~15 minutes)

Reflect using the *Programming a Rover Evaluation* worksheet

A. Hand out the *(C) Programming a Rover Evaluation* sheet and have students:

- List the criteria and constraints of the game that impacted the design and execution of your commands.
- Describe your algorithm for exploring the terrain and searching for rocks and explain how these steps met the constraints of the game.
- How did you balance the rover's movement and actions with its limited power supply in order to maximize the game score?

- Why are the sedimentary rocks of more scientific value than the volcanic rocks in the search for habitats on Mars?

6.0 Extensions

KODU GAME LAB

A. Have students work with the When-Do statements to change the dynamics of the game and the way the rover behaves. They can change when and how points are allotted, modify the speed of the rover, and decide whether the rover inspects, scans, or beams a rock using its laser spectrometer.

B. As a homework opportunity, *Kodu Game Lab* can be downloaded for free from home at www.kodugamelab.com. Have students explore the given tile code in the game and expand on it. They can add more rocks, edit the terrain, or even add another rover object!

7.0 Evaluation/Assessment

Use *(D) Programming a Rover Rubric* as a summative assessment. The rubric aligns with the NRC Framework, National Science Education Standards, and the instructional objective(s) and learning outcomes in this lesson.

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.

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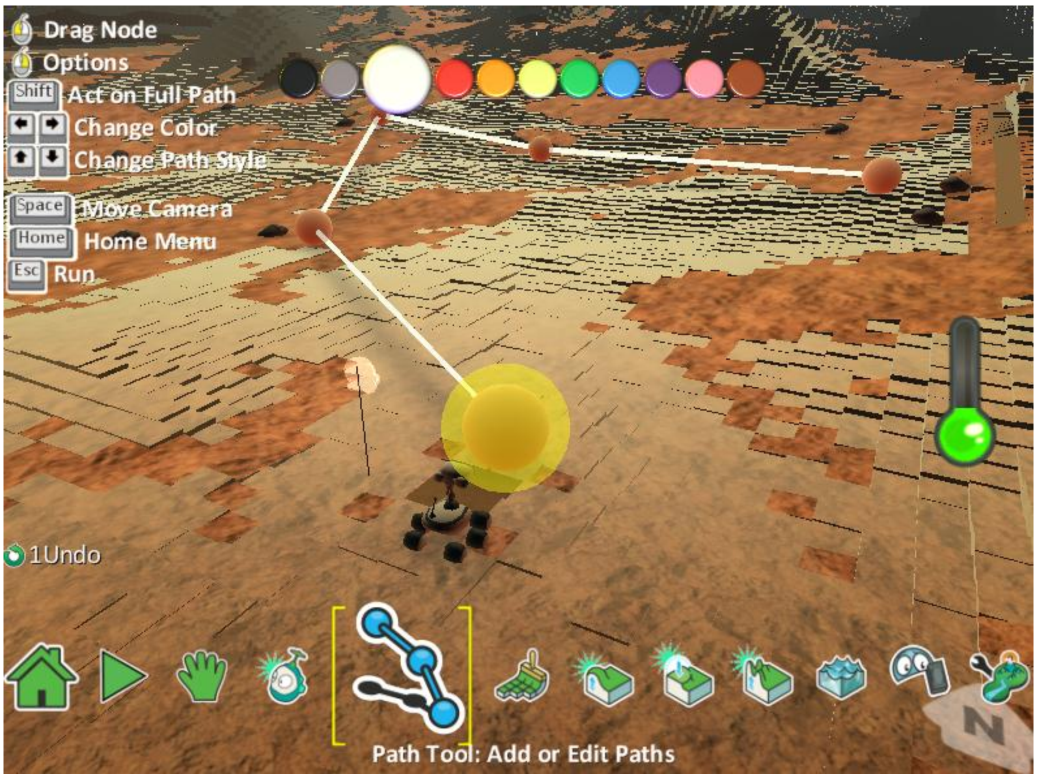
(A) How to Use the Kodu Path Tool

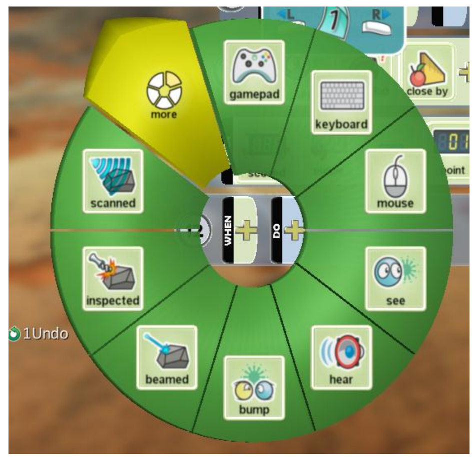
1. Open the Kodu tool menu by pressing the **Escape** key.
2. Select the **Path** tool.
3. A path is marked by a sequence of nodes (shown as spheres and lines). Click on a location to place a path node.
4. Continue to lay down nodes and press the **Escape** key to end the path.
5. You can change the color of the path using the left and right arrow keys.
6. Different colored paths could be useful indicators of different terrains.



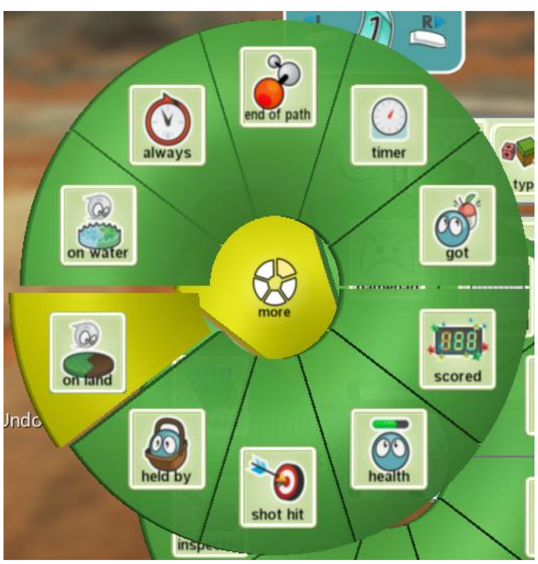
(B) Kodu When-Do Statements

1. Open the Kodu tool menu by pressing the **Escape** key.
2. You will create the following When-Do statements for lines 12 and 13 in the rover's program:

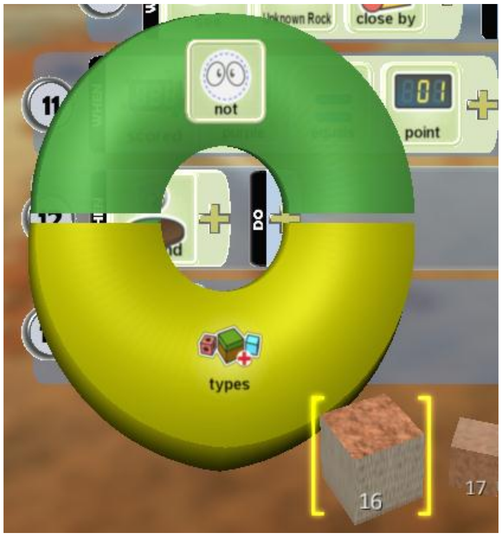
3. Click on the plus sign in the **When** section of statement 12 and select **more**.



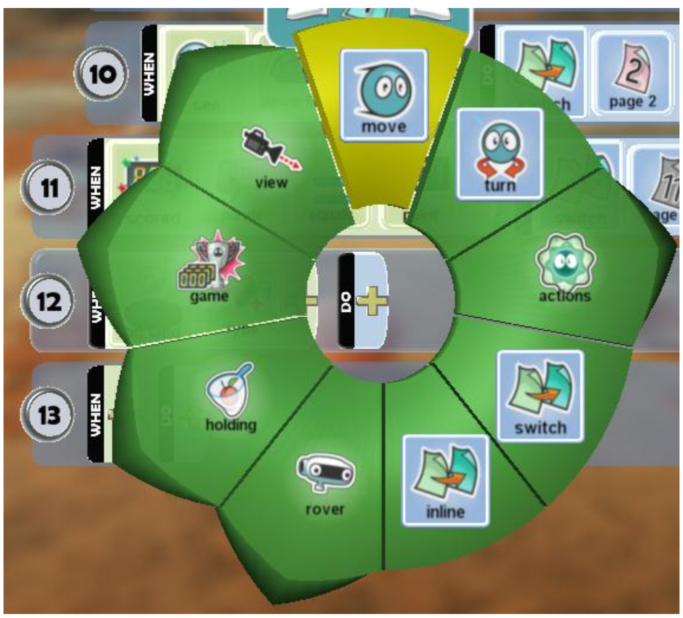
4. Click the **on land** tile.



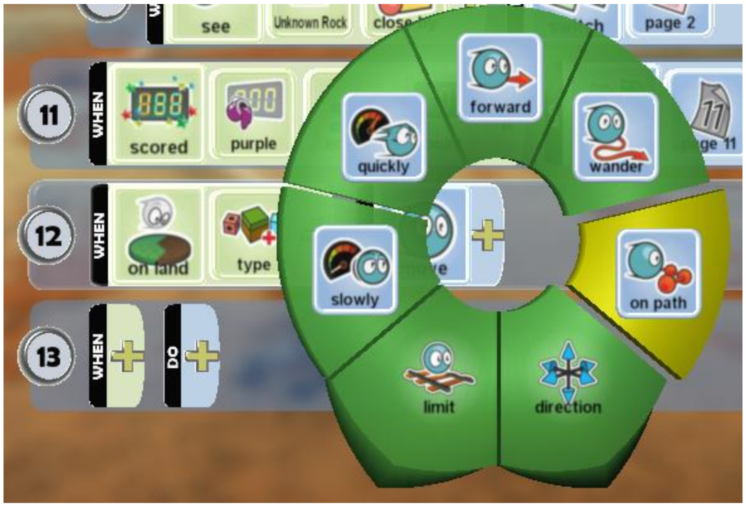
5. Click the plus sign next to the **on land** tile and choose **types** and then **material 16**.



6. Next, click the plus sign in the **Do** section and choose the **move** tile.

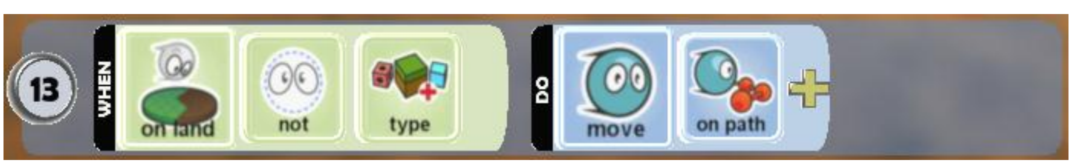


7. Then click on the plus sign next to the **move** tile and choose the **on path** tile.



8. When the rover is on land type 16, it should move on the path laid out, but slowly, simulating terrain that slows down the rover. Click on the plus sign next to the **on path** tile and select **slowly** three times. Be sure it shows in the code all three times.

9. Follow the same directions to program the rover to move on the path at normal speed when not on land type 16, as seen below:



10. Kodu's tile-based language allows you to experiment with the code without being frustrated by error messages resulting from syntax errors. A syntax error occurs when a user writes an instruction that the program cannot understand.

11. Test your coding and don't be afraid to test some more. The great thing about Kodu is that you can easily test your programming and make corrections.

(C) Programming a Rover Evaluation

NAME:_______________________________

1. List the criteria and constraints of the game that impacted the design and execution of the commands.

2. Describe your algorithm for exploring the terrain and searching for rocks and explain how these steps met the constraints of the game.

3. How did you balance the rover's movement and actions with its limited power supply in order to maximize the game score?

4. Why are the sedimentary rocks of more scientific value than the volcanic rocks in the search for habitats on Mars?

(D) Teacher Resource. Programming a Rover Rubric (1 of 4)

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 design an algorithm that reflects criteria and constraints.

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

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

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).

Abilities of Technological Design: 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).

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1a. To translate a natural language procedure into a programming language algorithm.	Students accurately translated all of the instructions in the natural language procedure into a programming language statement.	Students accurately translated most of the instructions in the natural language procedure into a programming language statement.	Students accurately translated some of the instructions in the natural language procedure into a programming language statement.	Students did not accurately translate any of the instructions in the natural language procedure into a programming language statement.

(D) Teacher Resource. Search and Explore Mars Rubric (2 of 4)

Related Standards (will be replaced when new NRC Framework-based science standards are released):
National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

National Science Education Standards (NSES)
(D) Earth and Space Science: Structure of the Earth System
Landforms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and depositions of sediment, while destructive forces include weathering and erosion (Grades 5-8: D1c).

Some changes in the solid earth can be described as the “rock cycle.” Old rocks at the Earth’s surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues (Grades 5-8: D1d).

Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers, with each having a different chemical composition and texture (Grades 5-8: D1e).

National Science Education Standards (NSES)
(D) Earth and Space Science: Earth’s History
Fossils provide important evidence of how life and environmental conditions have changed. (Grades 5-8: D2b).

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1b. To differentiate the visual characteristics of volcanic and sedimentary rocks and their scientific significance.	Students accurately identify different types of rocks and select them based on their scientific significance.	Students accurately identify different types of rocks and select them somewhat based on their scientific significance.	Students somewhat accurately identify different types of rocks and select them somewhat based on their scientific significance.	Students inaccurately identify different types of rocks and do not select them based on their scientific significance.

(D) Teacher Resource. Search and Explore Mars Rubric (3 of 4)

Instructional Objective 2: to execute an algorithm that reflects criteria and constraints.

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

National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

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).

Abilities of Technological Design: 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).

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO2a. To test, evaluate, and refine an algorithm.	Students performed multiple trials and generally increased scores with subsequent trials.	Students performed multiple trials and minimally increased scores with subsequent trials.	Students performed some trials and minimally increased scores with subsequent trials.	Students did not perform multiple trials and did not increase scores with subsequent trials.

(D) Teacher Resource. Search and Explore Mars Rubric (4 of 4)

Related Standards (will be replaced when new NRC Framework-based science standards are released):
National Science Education Standards (NSES)
UNIFYING CONCEPTS & PROCESSES

Grades K-12: Evidence, models, and explanations
Evidence consists of observations and data on which to base scientific explanations. Using evidence to understand interactions allows individuals to predict changes in natural and designed systems. Models are tentative schemes or structures that correspond to real objects, events, or classes of events, and that have explanatory power. Models help scientists and engineers understand how things work. Models take many forms, including physical objects, plans, mental constructs, mathematical equations, and computer simulations.

Scientific explanations incorporate existing scientific knowledge and new evidence from observations, experiments, or models into internally consistent, logical statements. Different terms, such as “hypothesis,” “model,” “law,” “principle,” “theory,” and “paradigm” are used to describe various types of scientific explanations.

As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance of criticism and uncertainty, and a clearer demonstration of the relationship between logic, evidence, and current knowledge.

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).

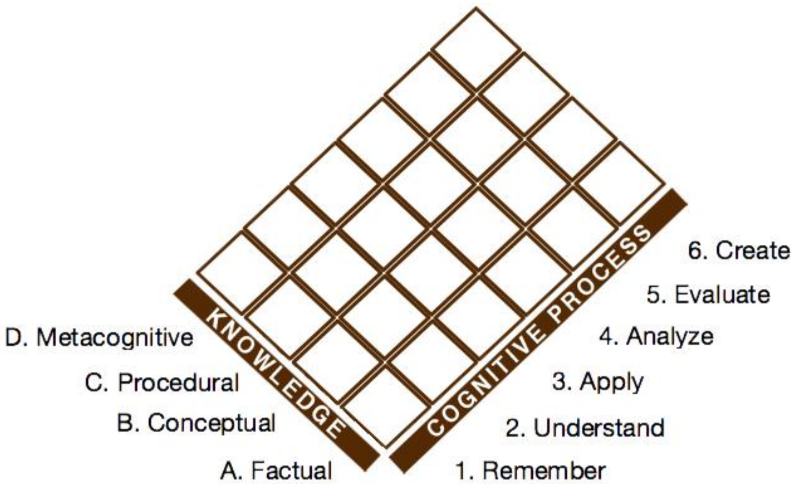
Abilities of Technological Design: Implement a Proposed Design
Students should organize materials and other resources, plan their work, make good use of group collaboration where appropriate, choose suitable tools and techniques, and work with appropriate measurement methods to ensure adequate accuracy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

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO2b. To monitor resource usage while achieving mission goals.	Students monitored resources and used them efficiently to achieve mission	Students monitored most resources and used them efficiently to achieve mission	Students monitored some resources and used them somewhat efficiently to	Students did not monitor resources and did not use them efficiently to achieve mission goals.

	goals.	goals.	achieve mission goals.	

(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.

IO1: To **design** an algorithm that reflects Earth science-related criteria and engineering constraints. (6.2; Cc)

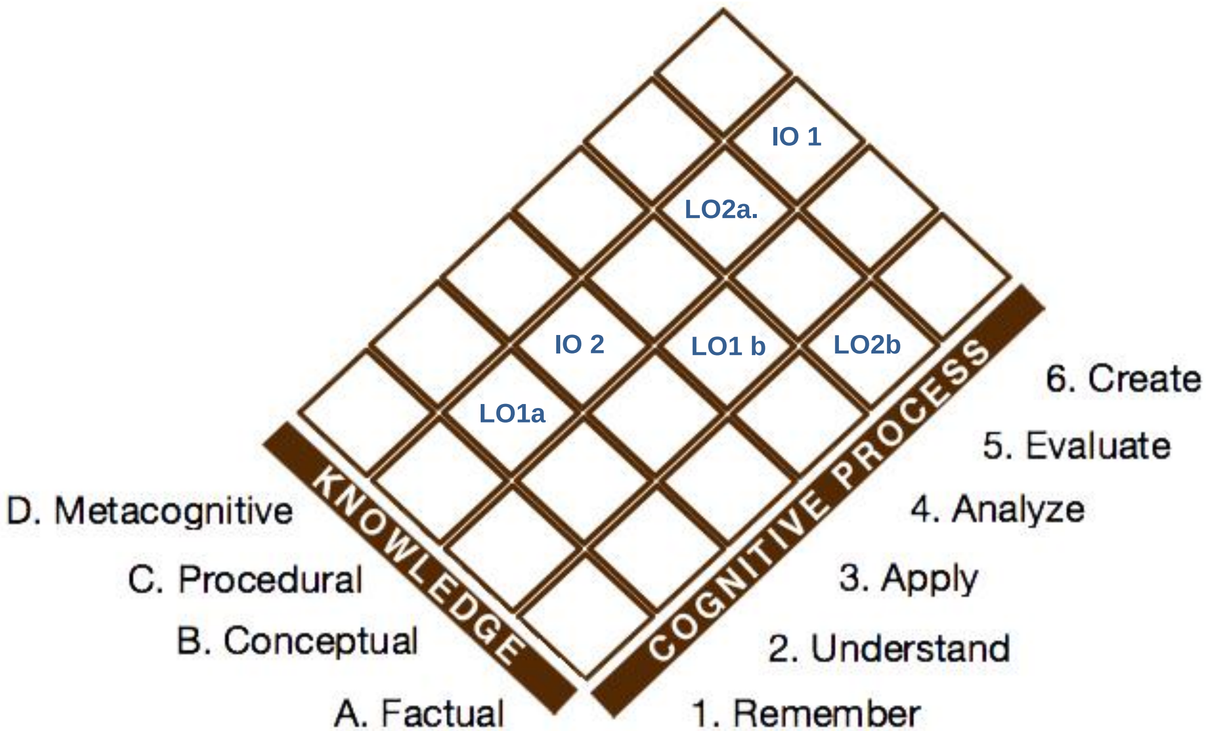
IO2: To **execute** an algorithm that reflects Earth science-related criteria and engineering constraints. (3.1; Cc)

LO1a. To **translate** a natural language procedure into a programming language algorithm. (2.1; Ca)

LO1b. To **differentiate** the visual aspects of volcanic and sedimentary rocks and their scientific significance. (4.1; Ba)

LO2a. To **test, evaluate, and refine** an algorithm**.** (5.1; Cc)

LO2b. To **monitor** the use of resources while achieving mission goals. (5.1; Ab)



(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 Procedure*) 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 previous 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 **design** an algorithm that reflects Earth science–related criteria and engineering constraints.
6.2: To design
Cc: Criteria for determining when to use appropriate procedures

IO2: To **execute** an algorithm that reflects Earth science–related criteria and engineering constraints.
3.1: To execute
Cc: Criteria for determining when to use appropriate procedures

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

LO1a: To **translate** a natural language procedure into a programming language algorithm.
2.1: To translate
Ca: Subject-specific skills and algorithms

LO1b: To **differentiate** the visual aspects of volcanic and sedimentary rocks and their scientific significance.

4.1: To differentiate
Ba: Classifications and categories

LO2a: **To test, evaluate, and refine** a procedure.
5.1: To check
Cc: Criteria for determining when to use appropriate procedures

LO2b: To **monitor** resource usage while achieving mission goals.
5.1: To monitor
Ab: Specific Details & Elements