A Microsoft/NASA Collaboration

Lesson 3

Mars Mission Simulation

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

WHAT STUDENTS DO: Design a Simulated Martian Environment and Program a Rover to Explore Mars Autonomously

Describe a rover's experience on Mars. Where would it land? What kinds of landforms might it encounter? What actions would it perform and where would it go? In this lesson, students will:

- Choose a rover's landing site on Mars.
- Create a 3D model of Martian terrain.
- Program the rover to explore it.
- Explain their rationale as they present their simulation.

Throughout the project's development, students will make substantive decisions about where the rover will land, what types of landforms it may encounter, what types of rocks it will find, what path it will take, and what actions it will perform. There will be a strong emphasis on the same decision-making processes in which NASA scientists and engineers engage during a real mission.

First, students will be presented with a number of possible landing sites. They will have to weigh the advantages and disadvantages of each site and support their decision for a particular site. Then, they will model the terrain at the site using Kodu's terrain editing tools.

Second, students will choose landforms (crater, mountain, volcano, canyon, ancient riverbed/lake, etc.) to model. They will show their understanding of how different types of rocks and minerals (volcanic, sedimentary) develop by selectively placing them at the different landforms. When they present their simulation, they will explain how they represented the landforms in Kodu and their rationale for the placement of specific rock types.

Third, students will learn that 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 sending these complex plans via uplink 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)? Students will program a rover to move autonomously from the landing site to the other landforms. The rover will be programmed to scan, inspect, beam, and take pictures of rocks and different areas.

In the last part of the lesson, students will present their simulation and explain their rationale for the rover's landing site, the landforms it encountered, and information about those landforms, what rock types it found, and how the rover was programmed.

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 construct** a simulation based on criteria and constraints
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*	

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 *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 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
- Explore
- Explain
- Elaborate
- Evaluate.

The **Engage** stage is used like a traditional warm-up to pique student curiosity, interest, and other motivation-related behaviors and to assess students' prior knowledge. The **Explore** step allows students to deepen their understanding and challenges existing preconceptions and misconceptions, offering alternative explanations that help them form new schemata. In **Explain**, students communicate what they have learned, illustrating initial conceptual change.

The **Elaborate** phase gives students the opportunity to apply their newfound knowledge to novel situations and supports the reinforcement of new schemata or its transfer. Finally, the **Evaluate** stage serves as a time for students' own formative assessment, as well as for educators' diagnosis of areas of confusion and differentiation of further instruction. This five-part sequence is the organizing tool for the 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 Student Guide:

(A) Kodu Path Tool	- 1 per student
(B) Kodu When-Do Statements	- 1 per student
(C) Mars Mission Simulation Presentation	- 1 per student

The Curiosity Landing Site Selection lesson is courtesy of NASA's Mars Public Engagement Program.

From the *Teacher Guide*:

(D) Mars Mission Simulation Rubric

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

Optional Materials

Xbox 360 Wired Controller

3.0 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.
Delta	A nearly flat plain of sediment built up in horizontal layers over time, deposited by a river where it flows into a lake or ocean. Deltas are often triangular in shape and are named after the Greek letter “delta,” which also has a triangular shape.
Deposition	An act or process of depositing material through a natural process, usually by wind, water, or ice.
Digital elevation model	A digital 3-D representation of a surface created using elevation data.
Erosion	The removal and transportation of rock or sediment from its original location through a natural process, usually by wind, water, or ice; material that has been removed by erosion has been “eroded.”
Evaluate	To check the scientific validity or soundness.
Go-To site	A site where the Curiosity rover would have to travel some distance outside of the landing ellipse to get to the main feature of interest for that landing site.
Habitat	A place able to support life.
Igneous Rock	Rock formed when molten rock (magma) from deep within the Earth solidifies.
Inspect	To examine closely; in Kodu, this function activates a drill to inspect a rock (the “X” key on a keyboard or the “X” button on a controller).
Landform	A naturally-occurring surface feature.
Landing ellipse	An area in which Curiosity is most likely to land. The most probable landing location is exactly in the center of the ellipse, but

given uncertainties in the landing (such as wind), engineers provide a landing area rather than a precise landing point location.

Mineral	A naturally occurring solid with a specific chemical composition. A rock can be an aggregate of many minerals.
Organics	Carbon-based molecules that are the chemical building blocks of life as we know it.
Phyllosilicates	A special type of clay (a sedimentary rock) that can preserve signs of organics.
Preservation potential	How likely it is that an area has preserved evidence of habitable environments; areas with higher preservation potential are more likely to preserve this evidence.
Program	Coded instructions to perform a task.
Robotics	The use of machines to perform manual tasks.
Rock	A naturally occurring solid composed of one or more minerals.
Rock density	The number of rocks in a given unit of area. The more rocks in a region, the greater the value of the rock density for that region.
Rover	A small remotely-controlled vehicle that roams over terrain, taking photographs and gathering data about the 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.
Simulation	A representation of the characteristics of one system through the use of another system, oftentimes a computer program.
Syntax Error	An error in the sequence used to compose an instruction given to a computer.
Tele-operate	To operate remotely.
Terrain	Physical characteristics of an area of land.
Trade-off	An exchange of one 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).

4.0 Instructional Objectives, Learning Outcomes, Standards, & Rubrics

Instructional objectives, standards, and learning outcomes are aligned with the National Research Council's *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, which serves as a basis for upcoming "Next-generation Science Standards." Current National Science Education Standards (NSES) and other relevant standards are listed for now, but will be updated when the new standards are available.

The following chart provides details on alignment among the core and component NRC questions, instructional objectives, learning outcomes, and educational standards.

- Your **instructional objectives (IO)** for this lesson align with the NRC Framework and education standards.

- You will know that you have achieved these instructional objectives if students demonstrate the related **learning outcomes (LO)**.

- You will know the level to which your students have achieved the learning outcomes by using the suggested **rubrics** (see 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 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

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 produce** a simulation based on criteria and constraints	**LO1a. to translate a natural language procedure into a programming language algorithm.** **LO1b. to construct a model of terrain based on scientific data.** **LO1c. to test, evaluate, and refine an algorithm.** **LO1d. to differentiate between the visual characteristics of volcanic and sedimentary rocks and their scientific significance.** **LO1e. to evaluate a decision based on criteria and constraints.**	**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 **Implement a Proposed Design** **Grades 5-8:** E1c	***Rubrics in Teacher Guide***

Sections of this lesson courtesy of NASA's Mars Public Engagement Program

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).

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 is 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 (~25 minutes)

Mars Simulation

A. Tell students that they will be creating a simulation of Mars' terrain and the activities a rover might engage in as it explores Mars. To elicit prior knowledge of simulations, ask students to do a concept association exercise in which they write a list of concepts which are related to the idea of a simulation. Students may come up with flight and driving simulations, video games used for military training, and virtual reality.

B. Define simulation: A simulation is a representation of the characteristics of one system through the use of another system, oftentimes a computer program.

C. Ask: Why do we use simulations? What do scientists and engineers hope to learn by simulating a situation?

D. Introduce the scenario:
The students are scientists and engineers who are in the initial stages of designing a rover mission to Mars. They must first create a simulation of the landing site, the Martian terrain, and the activities that the rover will engage in while on Mars and then defend the rationale for their decisions in a presentation to their peers. Through the simulation, they will learn about the programming of a rover's movement and actions, the landforms which make up Mars' terrain, and the search for habitat on Mars.

E. To learn more about the Mars Science Laboratory, visit:
www.mars.jpl.nasa.gov/msl/

STEP 2: EXPLORE (~45 minutes)
Terrain Editing and Rover Programming

<u>Pair Programming</u>

A. Students will work two to a computer and utilize a method called "pair programming."

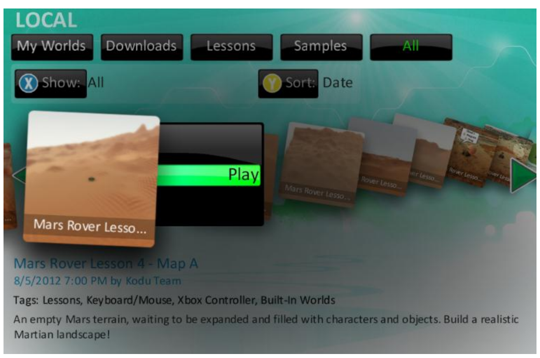
B. One student will act as the "driver." The driver is the only person to touch the keyboard and mouse or controller.

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

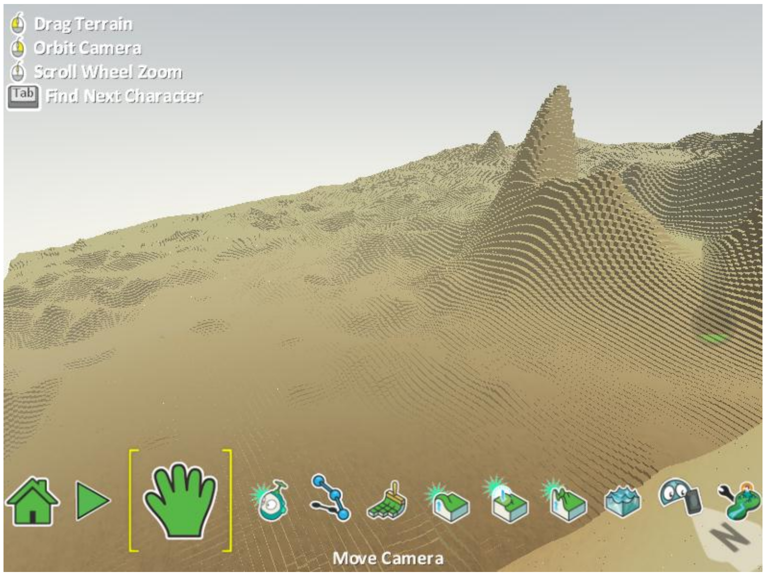
D. They should switch every 5 to 10 minutes throughout the class period to allow both students to perform the different roles.

<u>Terrain</u>

A. Show students how to open the Mars Mission Simulation world in Kodu. There are a number of maps to choose from.



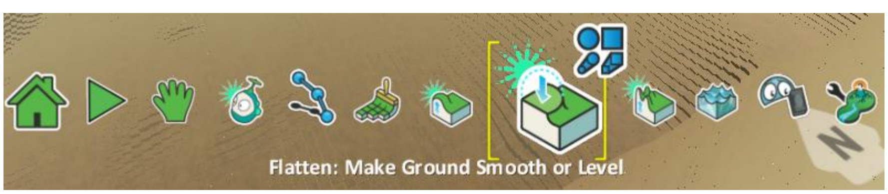
B. Demonstrate how to manipulate the camera so they can observe the entire world.
    a. Press the Escape key on the keyboard to pause the game and reveal the Kodu tool menu.
    b. Select the Move Camera tool (it looks like a hand).
    c. Follow the instructions in the top left of the screen to manipulate the camera. Zoom out to see more of the world.



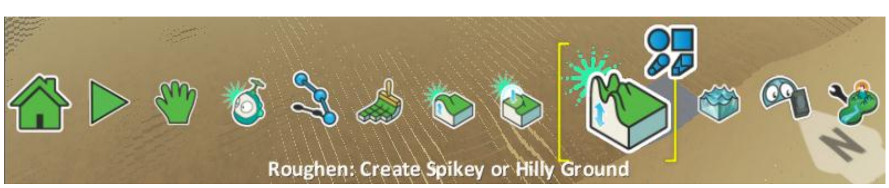
C. Have students experiment with Kodu's terrain editing tools.
   a. The ground brush paints, adds, and deletes terrain. There are options to choose the material type, brush type, and brush size.

   b. **Up/Down** creates hills and mountains or valleys, craters, and canyons.

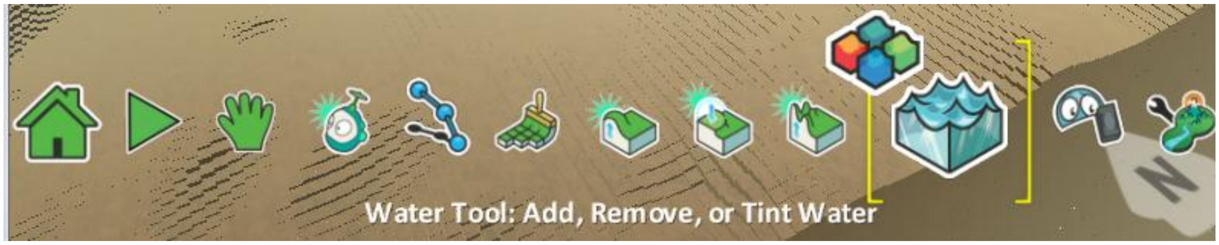
   c. **Flatten** makes the ground smooth or level.



   d. **Roughen** creates hilly or spikey land.



e. The **Water Tool** adds, removes, or tints water.



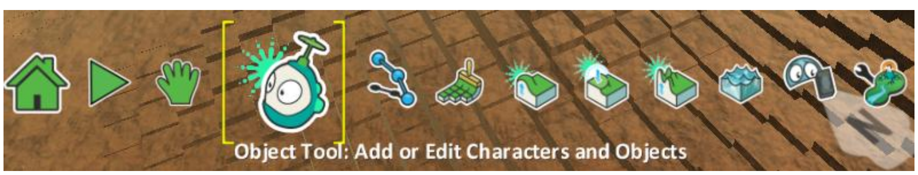
D. If they need help, have them view the Terrain tutorials at:
   a. http://csamarktng.vo.msecnd.net/kodu/4_Kodu_Terrain_gamepad.wmv
   b. http://csamarktng.vo.msecnd.net/kodu/5_Kodu_Terrain_keyboard.wmv

E. They should practice by creating a crater and a volcano.

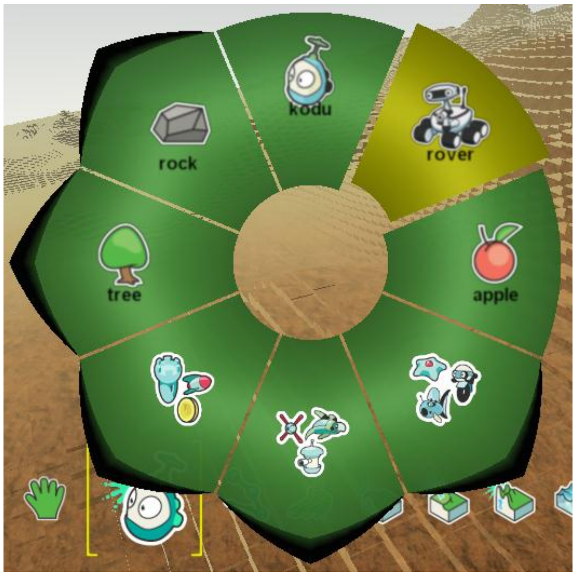
Program the Rover to Move Along a Path

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

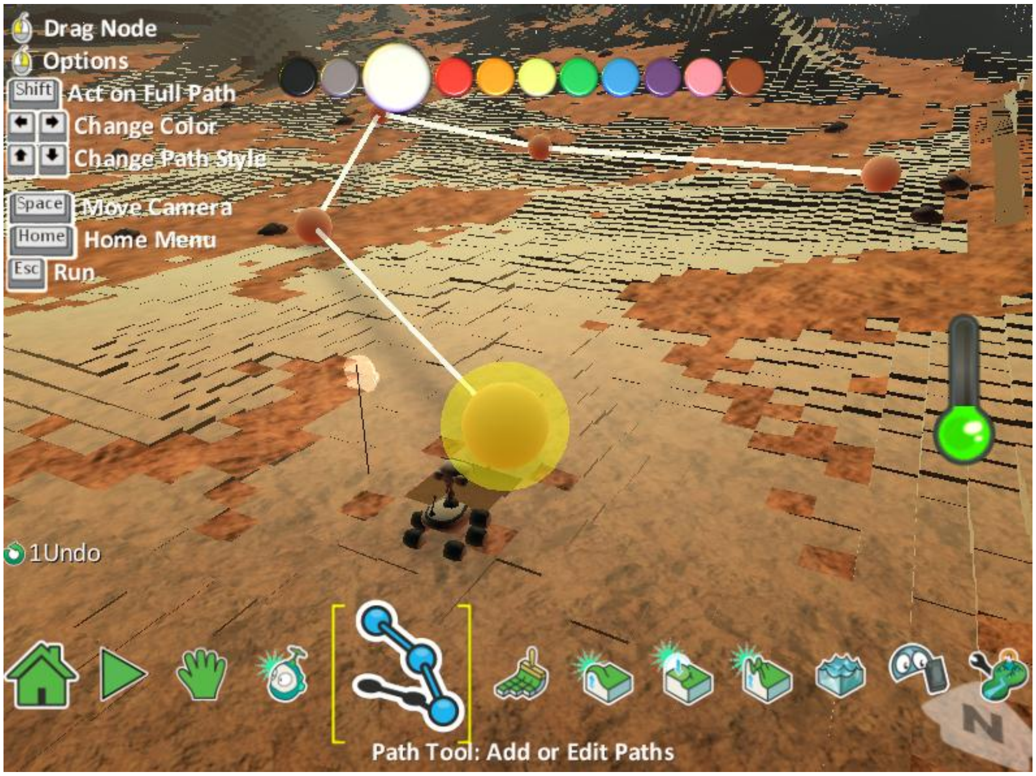
B. Place a rover in the world.
   a. To reveal the Kodu Tool menu (if not already there), press the Escape key.
   b. Select the **Object Tool**.



   c. Click on a location in the world and choose the **rover**.

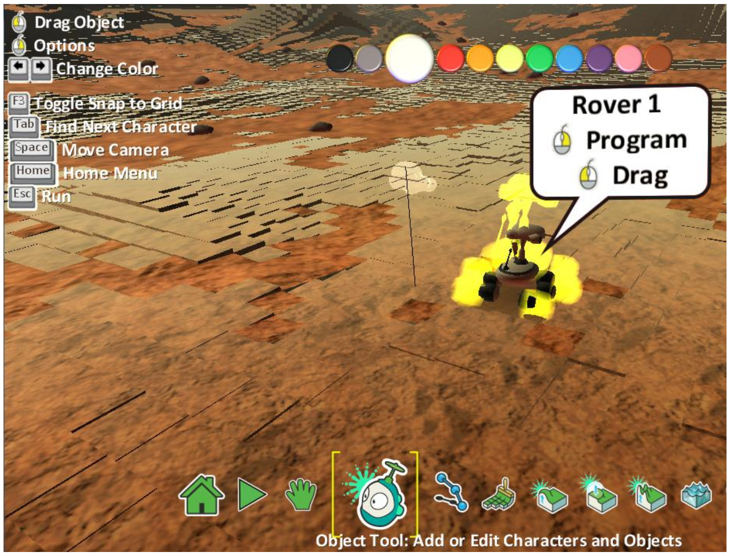


C. Next, students will designate a path. Have students refer to the *Kodu Path Tool* worksheet.
   a. Show students how to use the **Path Tool** to create the rover's path. A path is marked by a sequence of nodes. Select the **Path Tool** and click on a location to place a path node.

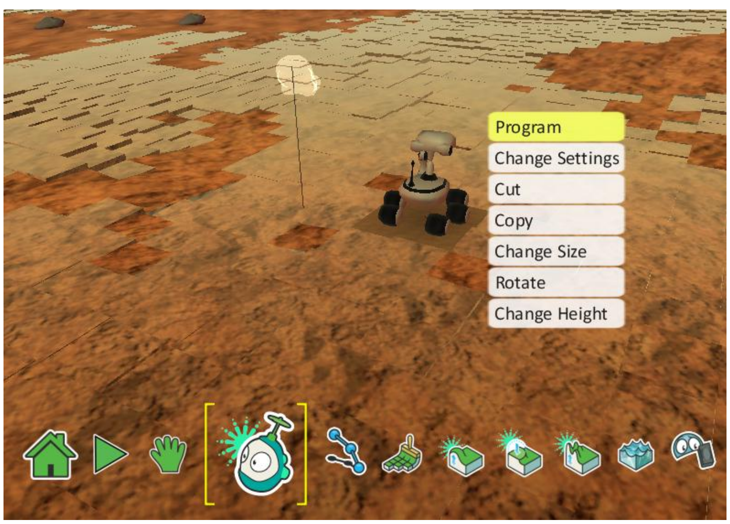


   b. Continue clicking to lay out the rover's path. Press Escape when the path is complete. As students lay down the nodes in the path, they should avoid the darker areas which will slow the rover down.

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.

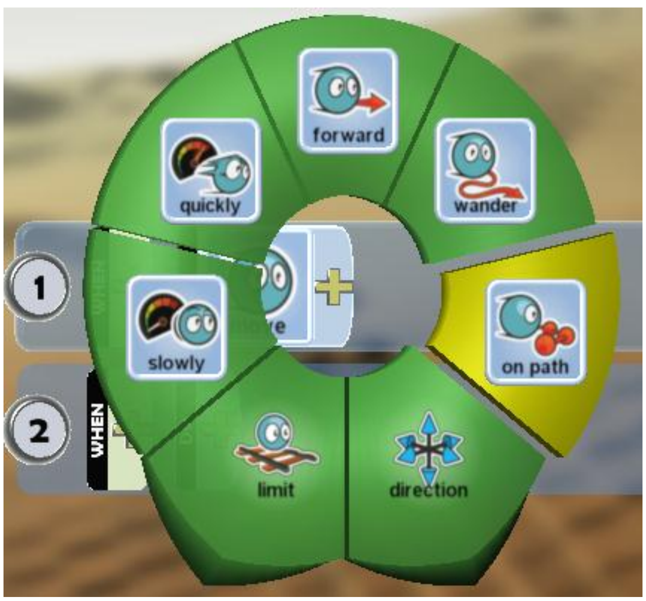


   c. Right-click the rover and then select **Program**.

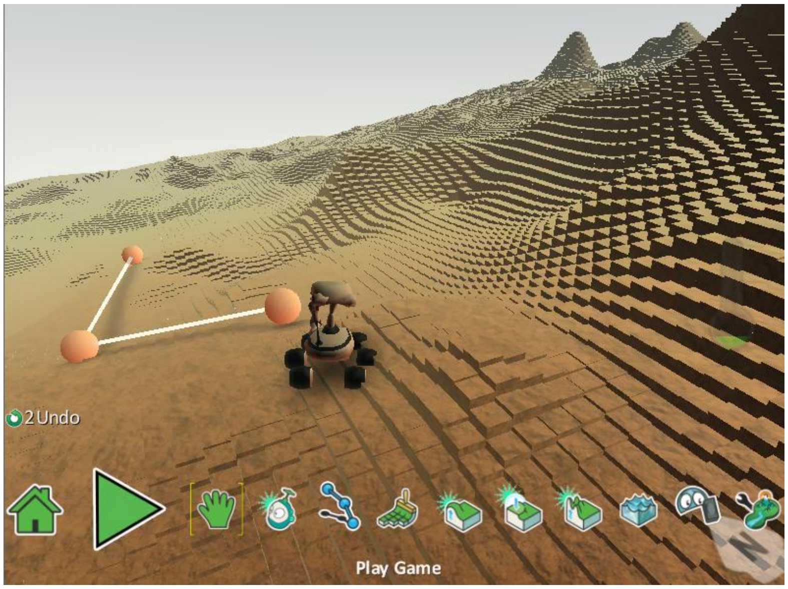


E. Students will program the rover to follow the path.
   a. Before explaining how to program the rover to follow the path, ask students to use a single statement to describe how the rover might know to follow the path using the When Do structure.
   b. Click on the plus sign in the **Do** section and select the **Move** tile.

c. Click on the plus sign next to the **Move** tile and select the **on path** tile.



d. Run the world by clicking the **Play Game** button and the rover should follow the path.



F. Students will later add other landforms, rocks, and program the rover to perform actions on the rocks.

STEP 3: EXPLAIN (~20 minutes)

Landforms and Rocks Explained

Landforms:

A. Mars' terrain exhibits many of the same features that exist on Earth, some just to a larger magnitude! There are craters, volcanoes (inactive), dry river valleys, dry river beds, mountains, dunes, and canyons. For example, *Olympus Mons* is a volcano that is almost three times the height of Earth's *Mount Everest* above sea level and is currently the tallest mountain on any planet in our Solar System. *Valles Marineris* is a valley that extends about the distance from California to New York and can be four times as deep as the *Grand Canyon* in some places. *Mount Sharp*, a mountain found in the middle of *Gale Crater*, is compared to some mountains on Earth in the image below:

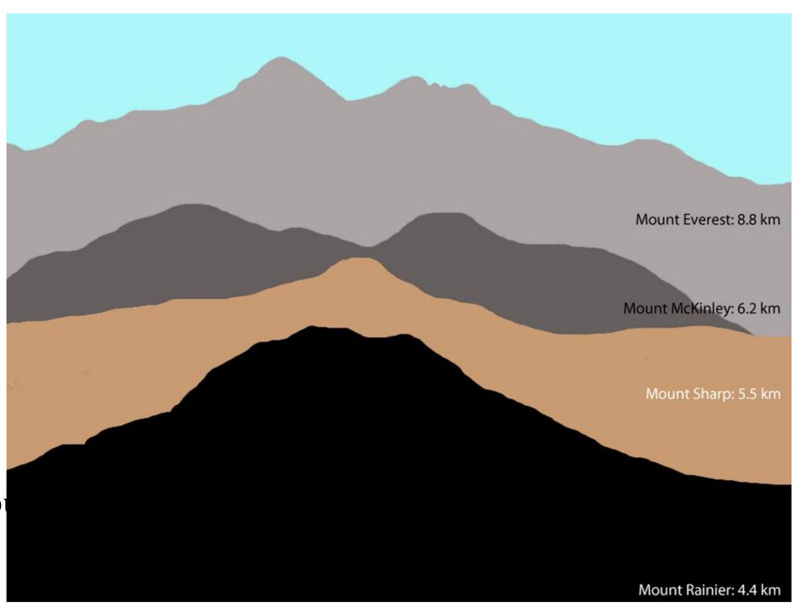


Image credit: NASA/JPL-Caltech/MSSS

B. Discuss how constructive and destructive forces, such as deposition and erosion, can create and change the landforms over time.

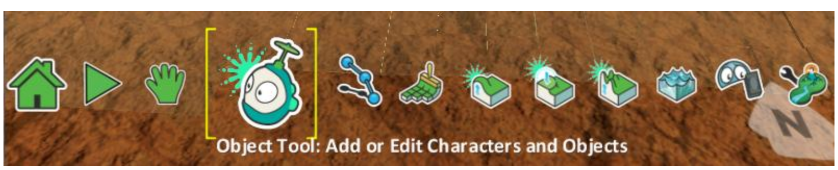
C. Students will later identify significant characteristics of particular landforms that they will model using Kodu's terrain editing tools.

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

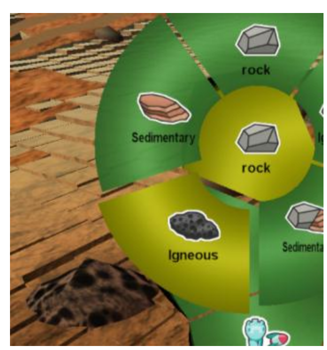
A. Ask: What is a rock? What is a mineral?
   a. A rock is a naturally occurring solid composed of one or more minerals.
   b. A mineral is a naturally occurring solid with a specific chemical composition. A rock can be an aggregate of many minerals.

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

C. Have students press the Escape key on the keyboard to reveal the Kodu Tool menu. Select the **Object Tool**.

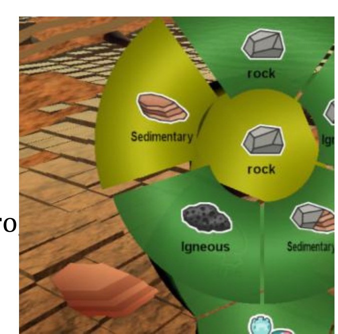


D. Ask students to place an igneous rock next to the landform (volcano or crater) where igneous rocks are most commonly found. They should select the volcano.



   a. Tell students to select the **Object Tool** and click on the desired location in the world.
   b. Select **rock** and then select **Igneous**.
   c. Ask students to explain where they placed the igneous rock. Volcanic rocks formed when magma from volcanic eruptions cooled (solidified) on Mars a long time ago.

E. Ask students to place a sedimentary rock next to the landform (volcano or crater) where sedimentary rocks are most commonly found. They should select the crater.



   a. Tell students to select the **Object Tool** and click on the desired location in the world.

b. Select **rock** and then select **Sedimentary**.
c. Ask students to explain where they placed the sedimentary rock. A sedimentary rock can be formed in a body of water when layers of sediment get compressed and cemented together. It can also form from deposits of volcanic ash or wind-blown deposits of small grains of rocks and minerals that also get compressed and cemented together.

STEP 4: ELABORATE (~150 minutes)

Mars Mission Simulation

Choosing a Landing Site:

A. Tell students that now that they have learned how to use Kodu to create terrain and program a rover, they will complete their simulation of a rover's experiences on Mars.

B. Students will research and select a landing site from four possible choices by completing the *Curiosity Landing Site Selection* lesson (approx. 100 minutes). Find the curriculum at http://mars.jpl.nasa.gov/participate/marsforeducators/soi/. This lesson is courtesy of NASA's Mars Public Engagement Program.

Modeling Terrain:

A. After picking a site, they will model the landing site and surrounding areas in Kodu.

B. They will pick three additional landforms to model in the surrounding area. The landforms should be a mix of landforms where students may find volcanic or sedimentary rocks.

C. After editing the terrain, students will place volcanic and sedimentary rocks near the appropriate landforms. While these landforms may or may not actually exist near each other on Mars, the creation of the landforms gives students a chance to demonstrate their understanding of what the landforms look like and where they might find volcanic and sedimentary rocks.

Programming the Rover:

A. Using the techniques they experimented with earlier in the lesson, students will design and program the rover's movement and actions as it explores the newly-created terrain.

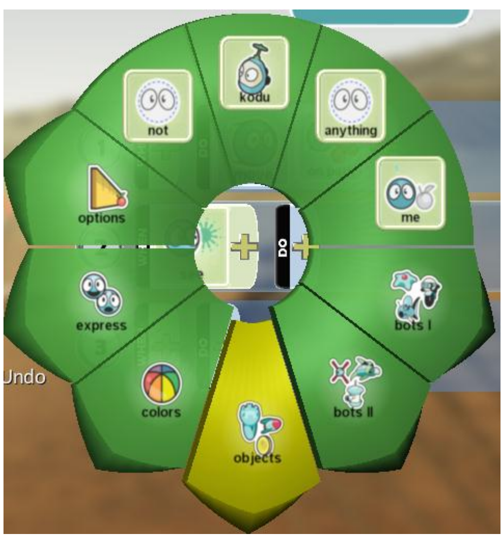
B. Each pair of students will act as the team of scientists and engineers who are tasked with deciding where the rover will go and what it will do every day. They should first write down their ideas as a natural language procedure. They do not need to use Kodu terminology. For example:
   a. Go to the group of rocks near the crater.
   b. Scan them.

c. Only inspect the sedimentary rocks.
d. Move to the river bed.

C. Next, students will translate their natural language procedure into Kodu's tile-based language. This process of deciding what the rover will do and translating it into a form the rover can understand mimics what the actual NASA scientists and engineers do to command the rover Curiosity.

D. Explain how to program the rover to perform an action on a rock along a path. For example: Beam an igneous rock.
   a. In statement 2 of the rover's code, click on the plus sign next to the When section and select the **see** tile.

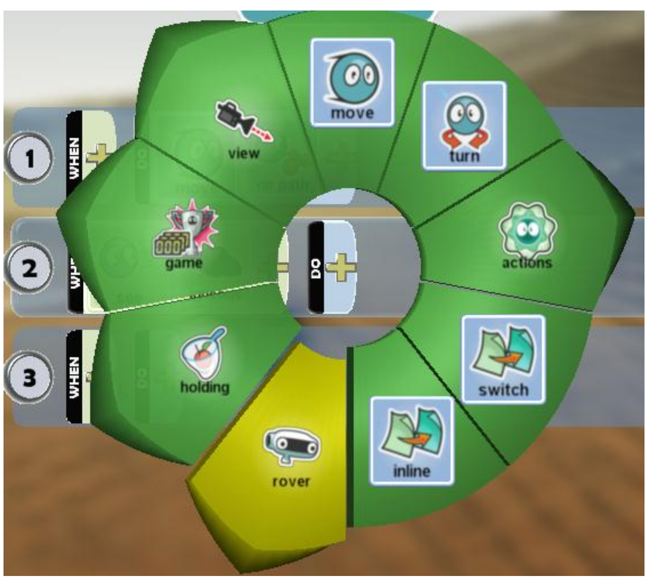
   b. Click on the plus sign next to the **see** tile and select **objects**.



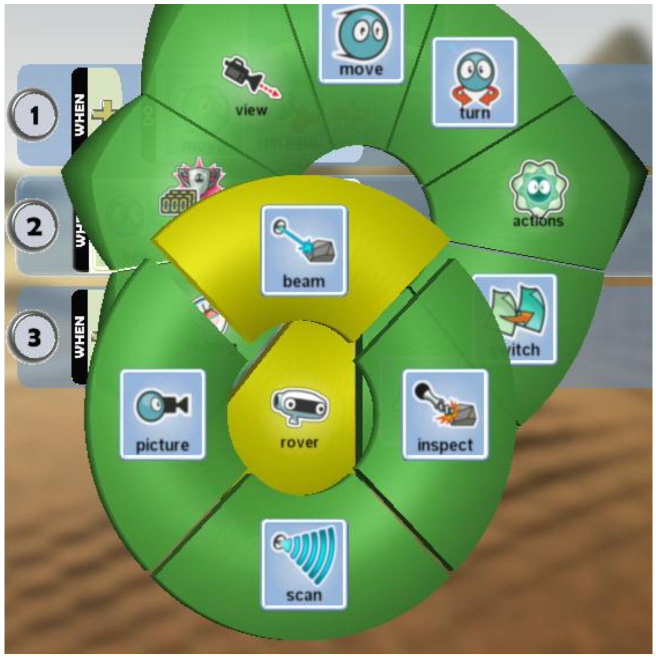
   c. Select **Igneous rock**.

d. The statement should look like this so far:

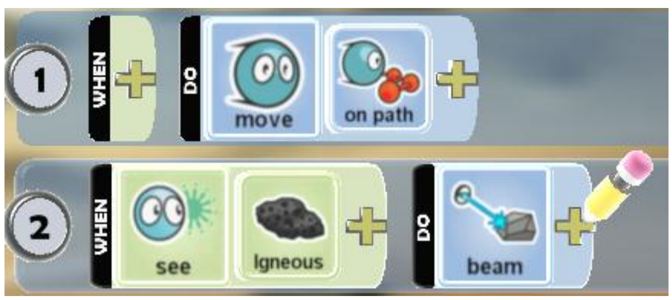
e. Click on the plus sign next in the **Do** section and select **rover**.



f. Select **beam**.



g. The rover’s code should now look like this:



E. Students will iteratively modify the rover’s path and program, run the world, and revise the path and program based on how they expect the rover to behave as it explores Mars.

F. For an advanced tutorial on programming behavior using multiple pages go to: http://csamarktng.vo.msecnd.net/kodu/10_Kodu_Pages.wmv

G. Students should switch pair programming roles multiple times.

STEP 5: EVALUATE (~60 minutes)

Presentations

A. Each group will present their work to the rest of the class. It is suggested that a central projector or monitor be used to present their Kodu worlds.

B. Have students complete the *(C) Mars Mission Simulation Presentation* worksheet. As students present their work to their peers, they will explain the rationale behind their decisions in their simulation:
   a. Where did the rover land? Why?
   b. What types of landforms did you model? How did those landforms develop on the Martian surface?
   c. What types of rocks are found on the Martian surface? Why did you place them in particular locations?
   d. What path did the rover take? What actions did it perform? How did it initiate those actions and movements? Describe your algorithm for exploring the terrain and searching for rocks.
   e. What did you learn from this activity that might influence a future rover mission to Mars?

6.0 Extensions

Landing Site Selection

Learn more about how the real landing site selection process took place. All of the information from the process is available to the public on the following website: http://marsoweb.nas.nasa.gov/landingsites/index.html and the process is summarized at http://mars.jpl.nasa.gov/msl/mission/timeline/prelaunch/landingsiteselection/

NASA Careers

Tell students that the same skills they used to choose a landing site and program the rover are the same skills scientists, engineers, and other employees at NASA use every day. Students can explore careers at NASA at: http://www.nasa.gov/audience/forstudents/5-8/career/index.html

Kodu Game Lab

Kodu Game Lab can be downloaded for free from home at www.kodugamelab.com. Have students expand on what they created in this lesson or create an entirely new world!

7.0 Evaluation/Assessment

Use *(D) Mars Mission Simulation 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

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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.

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Lantz, H.B. (2004). *Rubrics for Assessing Student Achievement in Science Grades K-12.* Thousand Oaks: Corwin Press.

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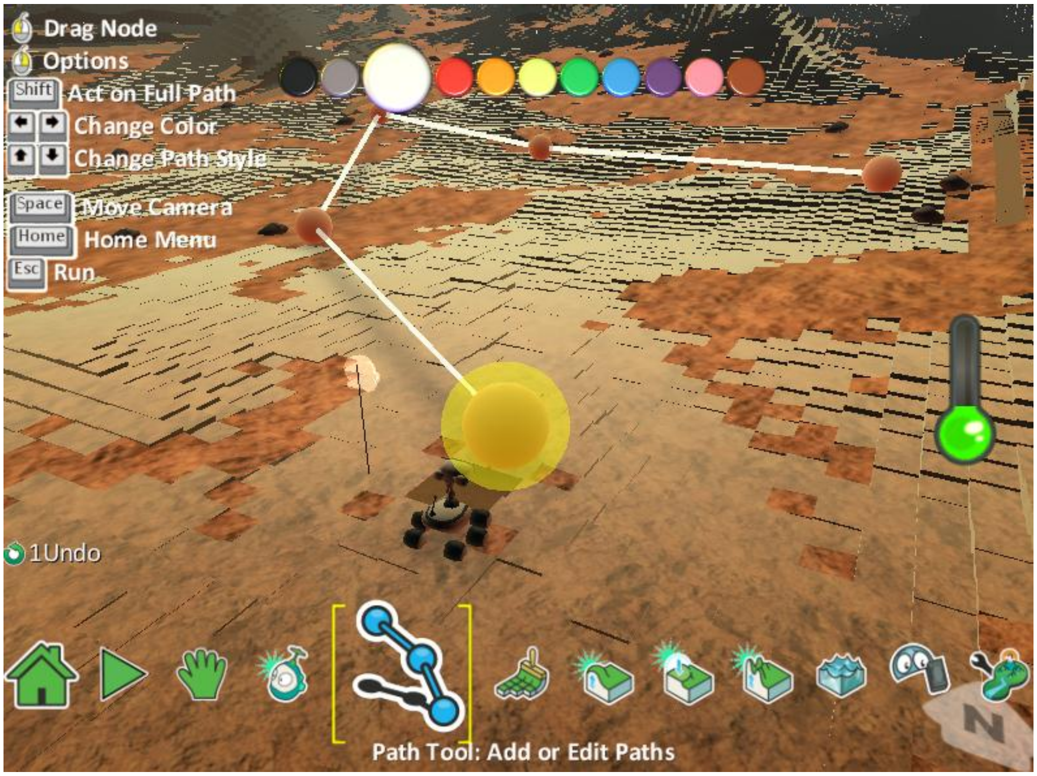
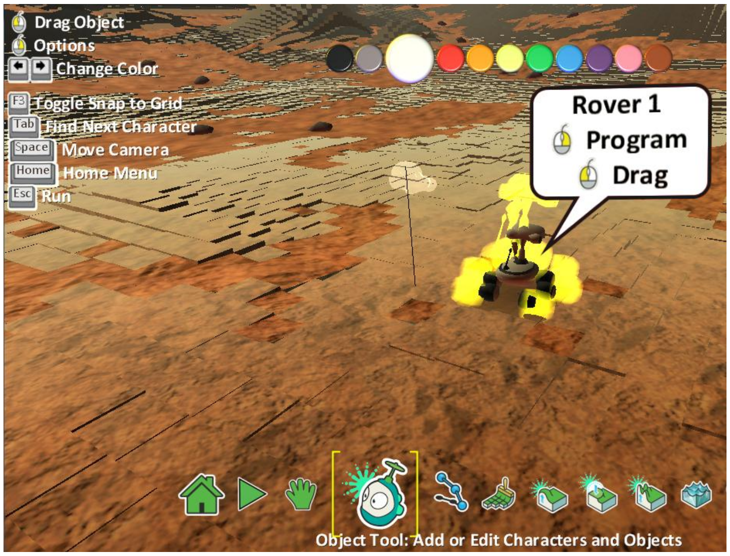
The Partnership for 21st Century Skills (2011). *A framework for 21st century learning.* Retrieved March 15, 2012 from http://www.p21.org/

(A) How to Use the Kodu Path Tool

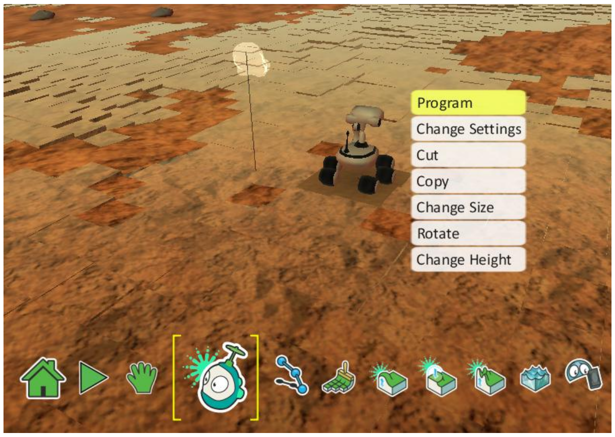
1. Reveal the Kodu tool menu by pressing the **Escape** key.
2. Select the **Path Tool**.
3. A path is marked by a sequence of nodes. Click on a location to place a path node.
4. Continue to lay down nodes and press **Escape** to end the path.
5. You can change the color of the path using the left and right arrow keys.



6. Once the path is laid out, 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.

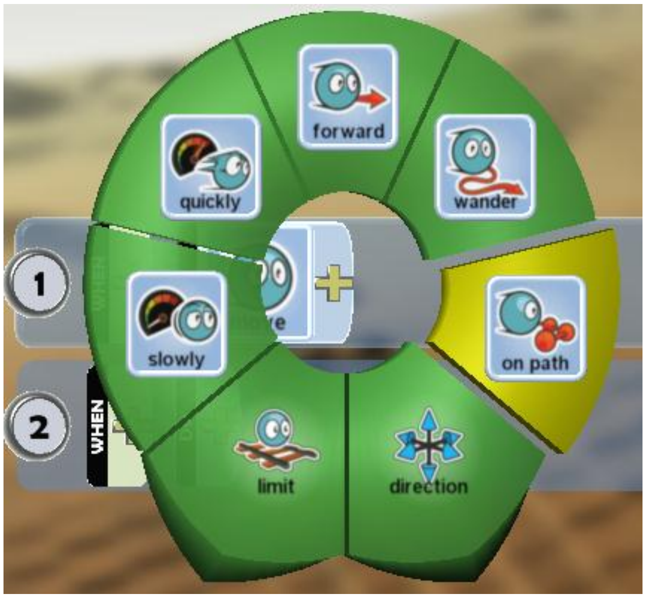


c. Right-click the rover and select **Program**.

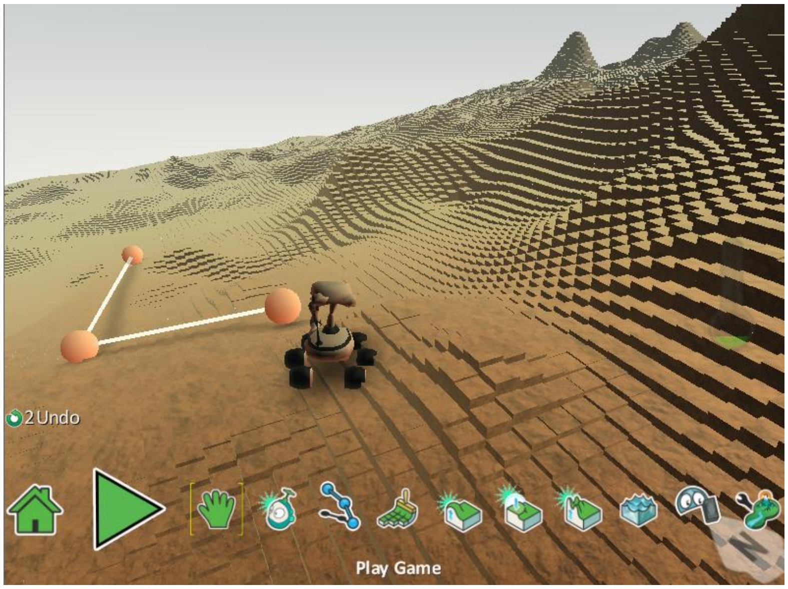


d. Click on the plus sign in the **Do** section and select the **move** tile.

e. Click on the plus sign next to the **move** tile and select the **on path** tile.



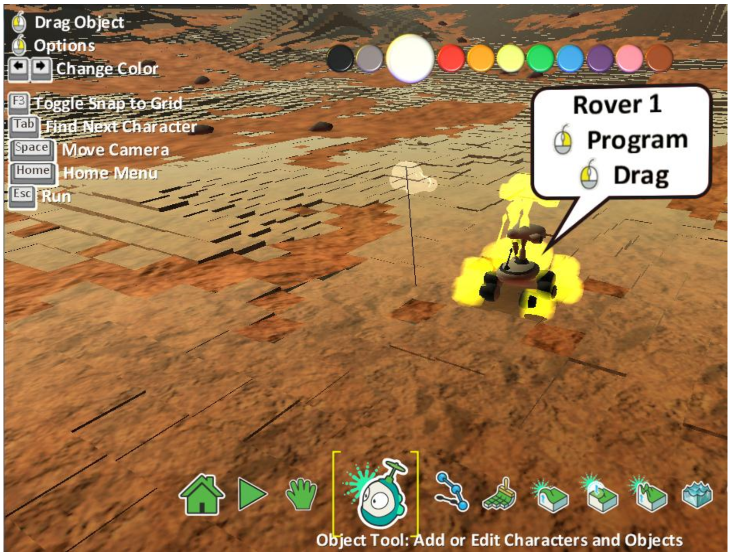
f. Run the world by clicking the **Play Game** button and the rover should follow the path.



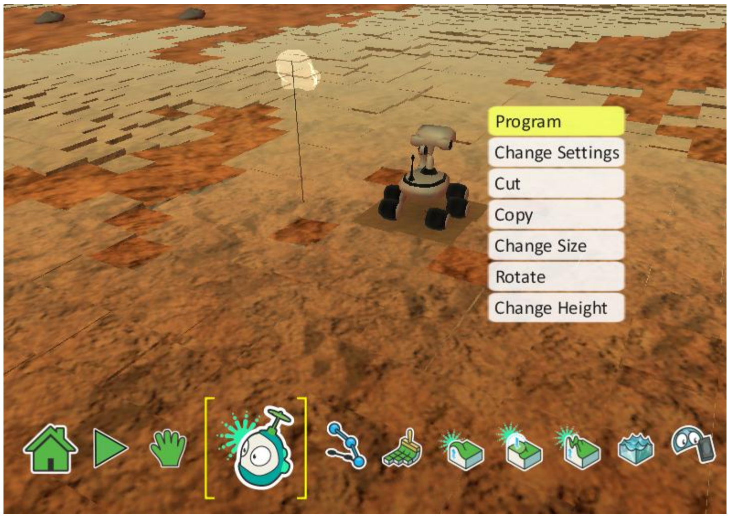
(B) Kodu When Do Statements

Example: Beam an Igneous Rock

1. Reveal the Kodu tool menu by pressing the **Escape** key.
2. Select the **Object Tool** and hover over the rover.

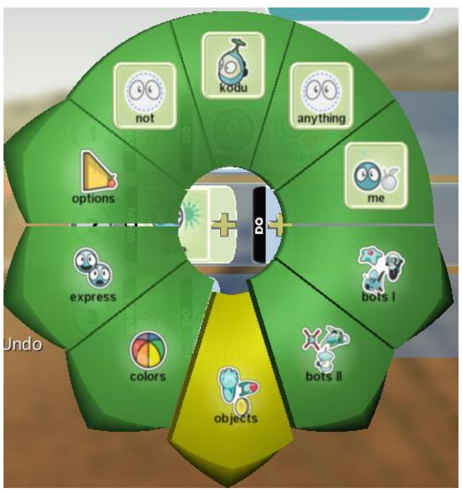


3. Right-click the rover and select **Program**.



4. Click on the plus sign next to the **When** section and select the **see** tile.

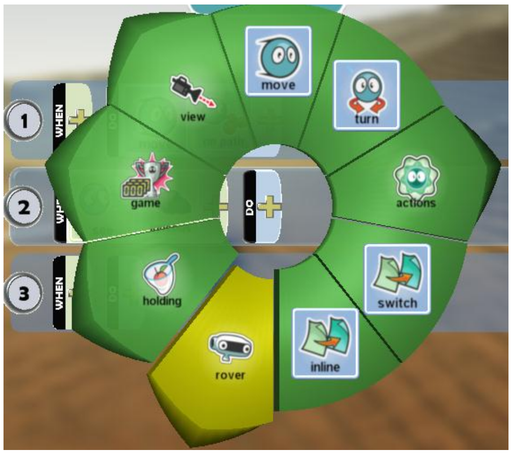
5. Click on the plus sign next to the **see** tile and select **objects**.



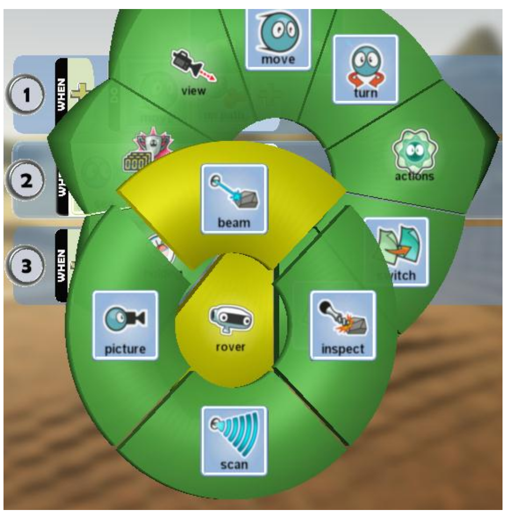
6. Select **Igneous** rock.

7. The statement should look like this so far:

8. Click on the plus sign next in the **Do** section and select **rover**.



9. Select **beam**.



10. The rover's code should now look like this:

(C) Student Worksheet: Mars Mission Simulation Presentation

Your team will present your simulation and explain your decisions. Prepare your presentation by answering the following questions. Make sure to address these questions in your presentation:

1. Where did the rover land? Why?

2. What types of landforms did you model? How did those landforms develop on the Martian surface?

3. What types of rocks are found on the Martian surface? Why did you place them in particular locations?

4. What path did the rover take? What actions did it perform? How did it initiate those actions and movements? Describe your algorithm for exploring the terrain and searching for rocks.

5. What did you learn from this activity that might influence a future rover mission to Mars?

(D) Teacher Resource. Mars Mission Simulation Rubric (1 of 5)

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 produce a simulation based on 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: Mars Mission Simulation Rubric (2 of 5)

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).

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 construct a model of terrain based on scientific data.	Students accurately reflected major characteristics of landforms in the model.	Students accurately reflected some of the major characteristics of landforms in the model.	Students reflected some of the major characteristics of landforms in the model.	Students did not reflect the major characteristics of landforms in the model.

(D) Teacher Resource: Mars Mission Simulation Rubric (3 of 5)

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
LO1c. to test, evaluate, and refine	Students performed multiple	Students performed	Students performed some	Students did not perform multiple

an algorithm.	trials and generally improved the accuracy of their algorithm with subsequent trials.	multiple trials and minimally improved the accuracy of their algorithm with subsequent trials.	trials and minimally improved the accuracy of their algorithm with subsequent trials.	trials and did not improve the accuracy of their algorithm with subsequent trials.

(D) Teacher Resource: Mars Mission Simulation Rubric (4 of 5)

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
LO1d. 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: Mars Mission Simulation Rubric (5 of 5)

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.

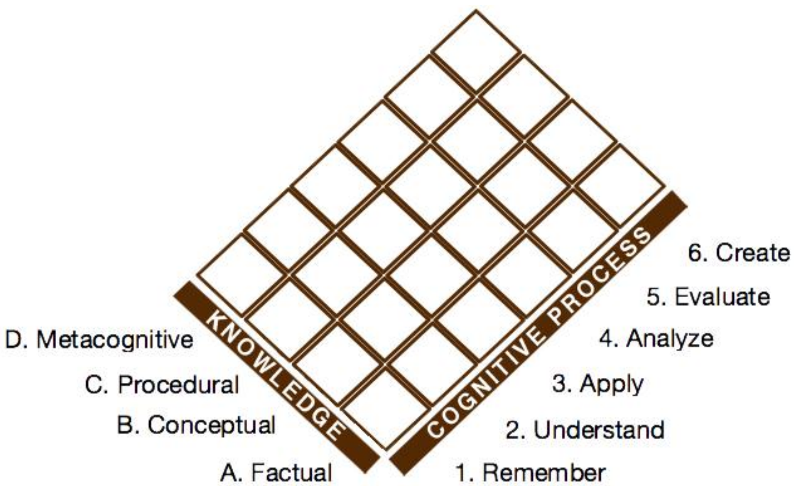
As students develop and as they understand more science concepts and processes, their explanations should become more sophisticated. That is, their scientific explanations should more frequently include a rich scientific knowledge base, evidence of logic, higher levels of analysis, greater tolerance 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).

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

Learning Outcome	Expert	Proficient	Intermediate	Beginner
LO1e. to evaluate a decision based on criteria and constraints.	Students evaluated all criteria and constraints when making a decision.	Students evaluated most criteria and constraints when making a decision.	Students evaluated some criteria and constraints when making a decision.	Students did not evaluate any criteria and constraints when making a decision.

(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.

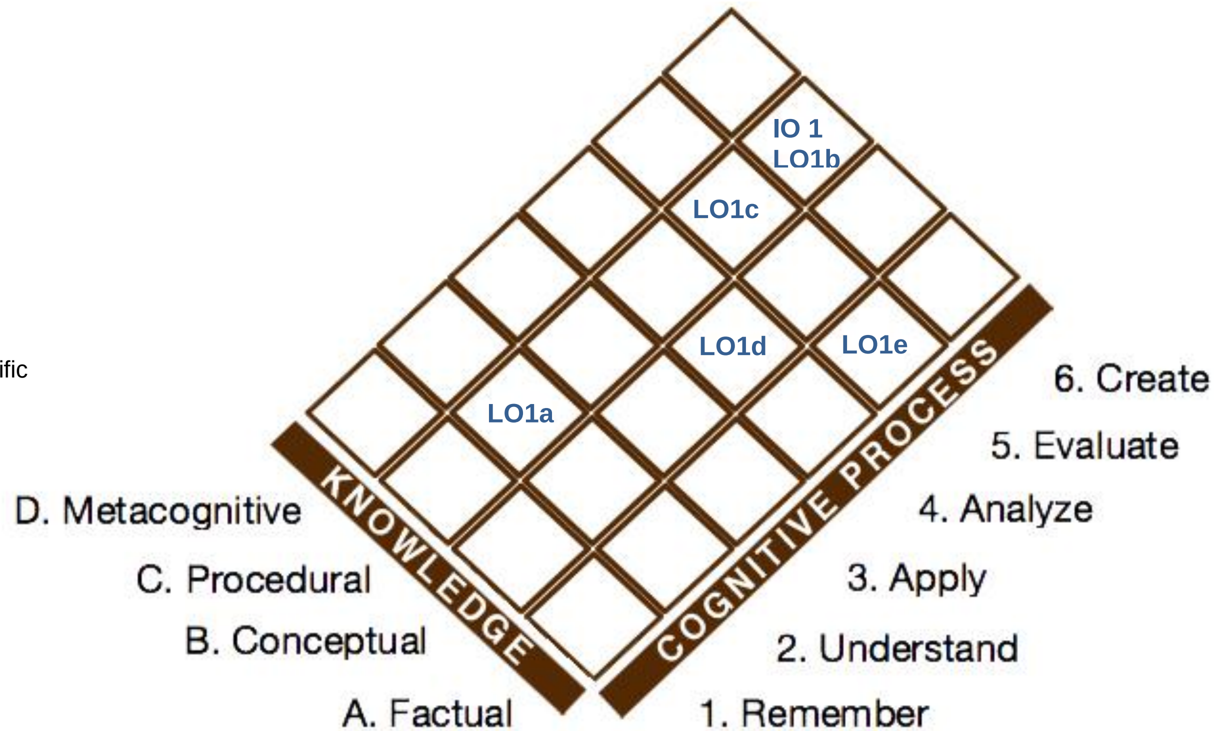
Knowledge	Cognitive Process
A. Factual **Aa:** Knowledge of Terminology **Ab:** Knowledge of Specific Details & Elements **B. Conceptual** **Ba:** Knowledge of classifications and categories **Bb:** Knowledge of principles and generalizations **Bc:** Knowledge of theories, models, and structures **C. 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 **produce** a simulation based on criteria and constraints (6.3; Cb)

- **LO1a.** to **translate** a natural language procedure into a programming language algorithm. (2.1; Ca)
- **LO1b.** to **construct** a model of terrain based on scientific data. (6.3; Cb)
- **LO1c.** **to test, evaluate, and refine** an algorithm**.** (5.1; Ca)
- **LO1d.** to **differentiate** the visual characteristics of volcanic and sedimentary rocks and their scientific significance (4.1; Ba)
- **LO1e.** to **evaluate** a decision based on criteria and constraints. (5.2; 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 prior page (E, 2 of 3) provides a visual description of the placement of learning outcomes that enable the overall instructional objective(s) to be met.

At the end of the lesson, students will be able

IO1: to **produce** a simulation based on criteria and constraints
6.3: to design
Cb: subject-specific techniques and methods

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 construct** a model of terrain based on scientific data.
6.3: to check
Cb: subject-specific techniques and methods

LO1c: **to test, evaluate, and refine** an algorithm
5.1: to check
Ca: criteria for determining when to use appropriate procedures

LO1d: to **differentiate** the visual characteristics of volcanic and sedimentary rocks and their scientific significance

4.1: to differentiate
Ba: classifications and categories

LO1e: to **evaluate** a decision based on criteria and constraints. (5.2; Ab)
5.2: to evaluate
Ab: Specific Details & Elements