Amy Hurlock Zock
STEM METHODS

NASA ENDEAVOR: Methods of STEM Course 5 E Lesson Plan

Title of Lesson: SPHEROS in SPACE: pathway to learning

Theme: Space Exploration focusing on Mars

Grade Levels: 6-8 (This has been designed for use within a STEM LAB connections class as part of an introduction to computer programming course)

Estimated Time: 5-10 class periods
Students have been working within the theme of **Space Exploration** throughout their time in the STEM lab. They have previously worked with the engineering design process using *NASA's BEST Students Beginning Engineering, Science and Technology* curriculum designing and building satellites. Students have completed the *Marsbound! Mission to the Red Planet* activity created by NASA working collaboratively to plan a mission to mars from launch to landing. This lesson focusses on bringing their recent studies of Space Exploration as the context for developing a coding solution that will move their SPHERO robot autonomously through a simulated Mars landscape using a scaled drawing and pseudocode to communicate collaboratively with their team and to evaluate the effectiveness of their code.

NGSS Standards:

Engineering Design:

MS-ETS1-1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.

MS- ETS1-3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristic of each that can be combined into a new solution to better meet the criteria for success.

MS-ETS1-4. Develop a model to generate data for iterative testing and modification of a proposed object, tool or process such that an optimal design can be achieved.

Common Core State Standards:

RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table.)

MP.2. Reason abstractly and quantitatively.

7.EE.3 Solve multi-step real-life and mathematical problems posed with positive and negative rational numbers in any form (whole numbers, fractions, and decimals) using tools strategically. Apply properties of operations to calculate with numbers in any form; convert between forms as appropriate; and assess the reasonableness of answers using mental computation and estimation strategies.

7.SP Develop a probability model and use it to find probabilities of events. Compare probabilities from a model to observed frequencies; if the agreement is not good, explain possible sources of discrepancy.

NGSS Disciplinary Core Ideas

ETS1.A: Defining and Delimiting Engineering Problems:

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

ETS1.B: Developing Possible Solutions

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

ETS1.C: Optimizing the Design Solution

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

GEORGIA Standards of Excellence:

SCIENCE:

S7CS4 – Students will use tools and instruments for observing, measuring, and manipulating equipment and materials in scientific activities.
S7CS5 – Students will use the ideas of system, model, change, and scale in exploring scientific and technological matters.

STANDARDS FOR TECHNOLOGY LITERACY:

Standard 9 – Students will develop an understanding of engineering design.
Standard 10 – Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.
Standard 11 – Students will develop the abilities to apply the design process**.**

STEM STANDARDS:

ENGR-STEM 3 – Students will design technological problem solutions using scientific investigation, analysis and interpretation of data, innovation, invention, and fabrication while considering economic, environmental, social, political, ethical, health and safety, manufacturability, and sustainability constraints.
ENGR-STEM 4 – Students will apply principles of science, technology, engineering, mathematics, interpersonal communication, and teamwork to the solution of technological problems

COURSE STANDARDS: Information Technology Career Cluster Introduction to Digital Technology

IT-IDT-9 Design, develop, test and implement programs using visual programming.

IT-IDT-9.1 Utilize drag and drop software to develop programs.

IT-IDT-9.3 Explain how sequence, selection, iteration are building blocks of algorithms.

IT-IDT-9.5 Use various debugging and testing methods to ensure program correctness.

Crosscutting Concepts

Influence of Science, Engineering, and Technology on Society and the Natural World

- All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of people and the natural environment.
- The uses of technologies and limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions.

Nature of Science

Science Investigations use a variety of Tools and Methods:

- Science investigations use a variety of methods and tools to make measurements and observations.
- Science investigations are guided by a set of values to ensure accuracy of measurements, observations, and objectivity of findings

Science is a Human Endeavor:

- Scientists and engineers rely on human qualities such as persistence, precision, reasoning, logic, imagination and creativity.
- Scientists and engineers are guided by habits of mind such as intellectual honesty, tolerance of ambiguity, skepticism and openness to new ideas.

Learning Objectives:

- Students will work collaboratively to analyze the constraints of a given course on the Mars board.
- Students will create a scaled drawing and map to use for planning their (Sphero) rover's path across the course and communicating their thinking.
- Students will decompose the path, identify patterns, abstract out their ideas to collaboratively develop an algorithm for their solution.
- Students will record their solution (algorithm) in pseudocode with their map to be used as a guide when coding their rover (Sphero).
- Students will incorporate sequential blocks from Sphero Edu to construct their code.
- Students will work collaboratively to explain how sequence, selection, and iteration are building blocks of algorithms.
- Students will check their code against their pseudocode when confronted with obstacles or difficulties executing their algorithm.
- Students will manipulate the direction, speed, and duration of a ROLL block in Sphero and LED change and fade blocks by adjusting the variables.
- Students will create and use a chart to record their test of each iteration of their code.
- Students will present their mission to the group and teacher and explain their process.
- Students will reflect on the design engineering process, collaboration, and use of tools such as their scaled map and pseudocode in a written journal entry.
- Through various discussions students will connect their work to the work of NASA as they explore Mars.
- Students will relate their maps to the data activities and discuss the constraints they faced in their challenge and how they relate to the constraints face by the NASA rovers today.

Guiding Questions:

- What are my next steps?
- How do the steps in my pseudocode relate to one another?
- Are there any repeated actions? How can we code this?
- How do duration and speed relate to distance?
- How does speed affect the transition between codes (turn angles)
- How does orientation affect direction?
- What is iterative programming?
- How can a scaled map help improve programming accuracy?

Materials:

•Tape measures
•Meter Sticks
•1 inch grid paper
•Student Design Notebooks
•Sphero Robots

•Chromebooks
•4' by 8' courses MARS
• Task cards for MARS
•Psuedocode sample
•Chart Paper, sticky nots and markers

•Sphero Basics Programming reference sheet
•Sphero Circle Orientation Reference Tools
• MARS map for DATA activity

Safety Considerations:

- Students need to be careful to use Spheros on board, and not on the ground, when others are nearby.
- Students must place computers fully on flat surfaces, so they do not fall.
- Sphero students and Drone students need to be aware of work zones especially when moving from place to place.
- Horseplay must not occur as it poses a serious potential risk for students and equipment.

Technology Integration:

- Students will use Chromebooks to program Sphero robots.
- Students will use SPHEROS to maneuver course on MARS board or SOLAR SYSTEM board.

Key Vocabulary:

Vocabulary:

- bearing
- blocks
- control
- duration
- events
- fade
- heading
- loop
- milliseconds
- orientation
- pseudocode
- sensor
- scale
- variable
- sequence
- selection
- iteration
- decompose
- pattern identification
- abstract out
- algorithm
- constraints
- limits

Authentic Scenario:

Many of NASA's missions are conducted by robots. While some robots can make decisions based on data received from sensors, humans must program the robots - we tell robots what to do and how to execute their missions. How can we program a Sphero on a robotic mission through a set course on Mars in one autonomous program?

Student Activities
Students will actively plan for, design, program, test, and improve a robotic mission through a set course (MARS or SOLAR SYSTEM). They will use Sphero Robots, Chromebooks with SPHERO EDU coding app, and Pseudocode to produce one autonomous program?

Teacher Activities -
The teacher will facilitate and monitor student learning. Teacher will model scale drawing and facilitate understanding of orientation and Block Code. Teacher will pose questions and listen for misconceptions so that she can clarify any misunderstandings students have after the Explore stage. She will not program student Spheros or create maps, pseudocode for students but will pose questions that will make students think about the process and engage them further. She will celebrate student success and recognize Engineering Habits of Mind regularly throughout the process.

Engage (Class Period #1-2):

Many of NASA's missions are conducted by robots. While some robots can make decisions based on data received from sensors, humans must program the robots - we tell robots what to do and how to execute their missions.

Teacher will introduce how NASA uses robots in different ways by pointing students to explore the Space Place website. Mars Rovers as Robots https://spaceplace.nasa.gov/mars-rovers/en/

Teacher will use the engaging context for data integration, **"Mapping with NASA for context and constraints"**

Guiding Questions:

What types of constraints would an actual Mars rover face in moving across the surface of Mars? What constraints do you need to consider when programming your Sphero to move across the surface of this challenge?

Goal: Students will use data gathered from the HiRISE Operations Center at the University of Arizona showing HiRISE DTMs (Digital Terrain Models) of Mars. They will analyze different data points for the constraints they would present to a typical Mars rover. Students will use the tools available from NASA on the Mars Trek site to map a journey for a rover. They will make predictions about the effects of the surface features on the travel of a rover.

Explanation: In order to program a SPHERO on a robotic mission through a set course representing Mars in one autonomous program students must understand the constraints of the course. Constraints are a critical component of the design process and a fact of life. By posing the question, "How do surface features affect the variables of speed and time when programming a SPHERO robot to travel across a course?" Putting this constraint in context with the actual constraints found on Mars builds authenticity for students and thereby increases student interest.

Procedure for data collection:

Students will use chromebooks and the DTM Map of Mars from the Digital Terrain Models on https://www.uahirise.org/hiwish/maps/dtms.jsp to collect data from at least three student selected points on the map.

Students will use the digital tools on https://trek.nasa.gov/mars/ to plan a path across Mars which must include:

- Three topographical features
- location (longitude and latitude)
- distance in KM between features
- Description of constraints

After students finish their map work, students will brainstorm a list of obstacles that a Mars Rover might encounter while traveling across Mars. Each constraint will be written on a separate sticky note. Students may include, but are not limited to, the following constraints: rough terrain, exposure to sun without cover, large craters, sandy surface, high winds and sand/soil blowing, extreme temperatures, cliffs and ridges, caves or caverns, high elevations and mountains, and low valleys.

Figure 1 CURIOSITY MARS ROVER (Greicius, 2017)

When the constraints list has been sufficiently generated (at least 10 constraints), students will be reminded of the science goals NASA has for exploring Mars that they previously worked with during the MARSBOUND activity early in the trimester. The Goals will be written on different chart papers across the front of the classroom (one goal per chart).

NASA's four Mars Exploration Program goals

i. Determine if life ever arose on Mars. All life, as we know it, requires water to survive. In fact, on Earth we have found life wherever there is water, even in places we didn't think life could exist, such as frozen deserts of Antarctica. Is the same thing true of Mars? Because of the low temperatures and thin atmosphere of Mars today, we know that there is currently no liquid water on the surface of the planet. But was that always true?

ii. Characterize the climate of Mars. If we can understand what the climate of Mars is like today and how it changes, we will have a better idea of what the climate of Mars was like in the past. The atmosphere of Mars is mostly carbon dioxide, but two other important components are water vapor and dust. With enough information, we can begin to create a picture of the overall climate of Mars now and what it may have once been like.

iii. Characterize the geology of Mars. Rocks and minerals on the surface of Mars can tell us a great deal about a planet's past. By studying surface morphology and patterns and types of features found on the surface, we can find a permanent record of the history of Mars in its rocks.

iv. Prepare for human exploration. Humans are naturally curious. No robot will ever have the flexibility of a human explorer, so someday we will want to travel to Mars ourselves to study the planet and its history directly. Because of the difficulty and the number of challenges, robotic spacecraft must pave the way for humans to follow. One important task is to study new techniques for entering the Martian atmosphere and landing on the surface. We will also need to understand the dangers humans will face on the surface of Mars.

(Arizona State University's Mars Education Program & NASA's Jet Propulsion Laboratory, 2014)

Students will work in groups to match constraints with the goals they may affect, determining which constraints must be addressed by NASA when programming their rovers for exploration on Mars. This is intended to get the discussion moving between students as they consider the difficulty of planning for these obstacles and unknowns.

When the discussion dies down and at least 10 minutes before the end of the class, the teacher will give a brief overview of the student MARS challenge. The challenge is created on a four by eight foot board with walls using a sheet with different materials underneath to make the terrain difficult to pass over easily. Materials that work well include bubble wrap, foam, small pebbles or rocks, play dough or clay shapes, crumbled newspaper etc. The sheet is laid over the materials and the Mars task cards are placed in various locations along the path. These cards do not have a specific order with the exception of the first card which encourages the students to establish an orientation for their rover (Sphero) by aiming it. After allowing students to explore the challenge course, the teacher presents them with the guiding question: How can we program a SPHERO on a robotic mission through a set course over Marts in one autonomous program? Students are left to think about this question as they leave class. This is intentionally designed as a cliff hanger so students will come back with more questions having had time to ponder the question**.**

Explore (Class Period #3):

SPHERO EXPLORATION: Students will practice manipulating the direction, speed, and duration of a ROLL block in Sphero and LED change and fade blocks. They will use the taillight aim function and make observations about how these changes affect the actions of the robot. Students will make observations about the effect of speed, duration, and direction on the movement of the Sphero over different mock terrains set up around the classroom.

Students will focus on the following guiding questions:

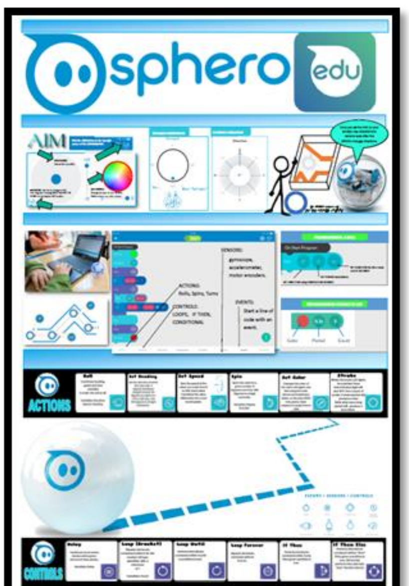


Figure 2 SPHERO coding reference sheet for display. It is also helpful to make a smaller version for students to keep in their design notebooks as a reference. (ZOCK, 2019)

- How do duration and speed relate to distance?
- How does speed affect the transition between codes (turn angles)
- How does orientation affect direction?

Exploration areas are designed to highlight some of the constraints students brainstormed yesterday in class. There will be an area with rough terrain, an area with a ridge or cliff, and an area with sloped sides like a mountain or crater. At each area students can experiment with first driving the sphero and then coding it to overcome the obstacle. They will make observations with their groups and post them in the area before moving to the next area.

Approximately 10 minutes before class change, students will be asked to clean up and gather around the challenge board. Teacher will lead a discussion connecting the exploration areas to different aspects of the board. Students will be reminded of the purpose of the ASK step in the Design Engineering Process. They will be encouraged to think about the things they will want to ask in order to be prepared to code this challenge. Students will write at least 2 questions in their journal as their ticket out of class.

Explain (Class Period #4-5):

INSTRUCTION:

Connect:

Teacher relates students back to the MARSBOUND activity reminding students that while they work through the ASK and IMAGINE steps of the Engineering Design Process, they will need to create an accurate map of the area for their mission. At this point some direct instruction of SCALE mapping may be necessary.

Support:
Display Sample Map, Basic Programming Functions, and Psuedocode with scaled map models. (Figures 3 and 4)

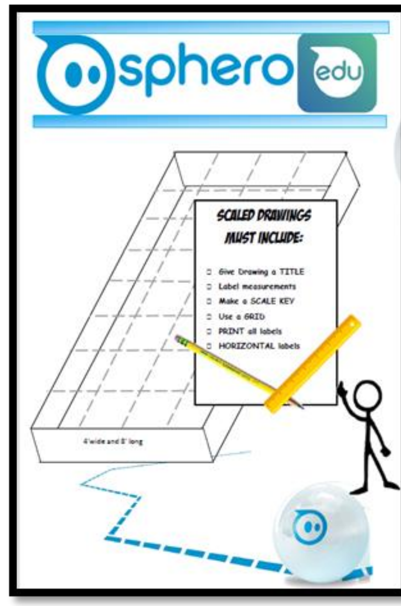


Figure 3 Reference for Scaled Map (Zock, 2019)

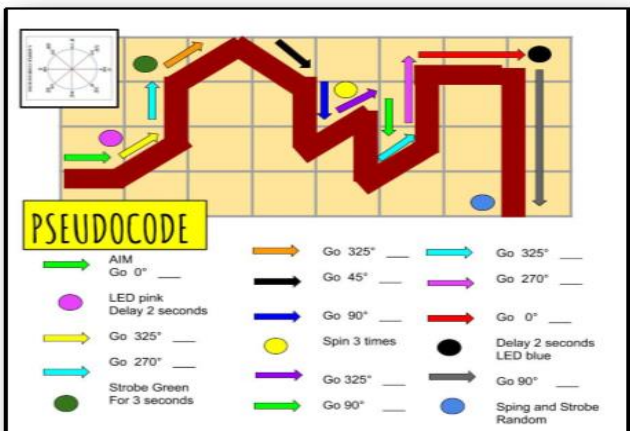


Figure 4 Pseudocode example for support. (ZOCK, 2019)

Pseudocode (IMAGINE): In the IMAGINE part of the process, students will need to put together a sequence of steps to get through the MARS mission course. This will be where they can record their algorithm or plan before aligning the code.

NOTE: It may be necessary to tape over the mission area to re-create the scale references. Pictured in figure 5 black tape has been used to create the one foot grid above the terrain. This is helpful for students who are having difficulty understanding scaled drawings. It is most effective if the struggling student helps taping off the grid, so they connect it to their own grid paper.

Figure 5 Students use taped grid to assist in making scaled drawings. (ZOCK, 2019)

Elaborate (Class Periods #6-8):

Students will work together to create, test, and improve code following their pseudocode plan. Each step of the code must be tested before adding the next step of code. Students will rotate through responsibilities of programmer and data collector switching rolls at each task card on the mission map. Students will record data and verify with pseudocode.

Figure 6 Students work to check their code solutions step by step. When they are satisfied with one step of their algorithm, they check it off on their pseudocode and go on to the next step. It may take several iterations to get a step working correctly. (ZOCK, 2019)

Evaluate (Class Periods #9-10):

Small Group Presentations:

Students will present their mission to the group and instructor and explain their process. These are relatively informal presentations. Students are still getting used to the idea that they may not always complete an entire challenge. Being able to articulate their thinking and the engineering process is the key. *If mission is not complete students will report of progress and identify obstacles you encountered during the process.

Student Reflection on Spheros in Space Mission:

While students are waiting for their turn to show their code and present their work to the teacher, they will have time for reflection. Using their design notebooks (see Figure 7), students will answer the following questions:

How did orientation, duration, and speed affect the path of the Sphero?

How did the scaled drawing help your coding process?

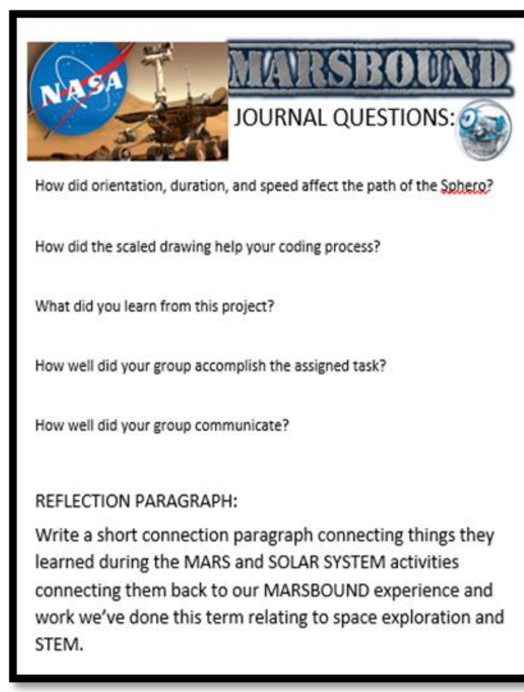
What did you learn from this project?

How well did your group accomplish the assigned task?

How well did your group communicate?

Connecting to Content:

Students will also write a short paragraph connecting things they learned during the MARS Mission Challenge activity connecting it back to our MARSBOUND experience and the work we've done this term relating to space exploration and STEM.



MARSBOUND

JOURNAL QUESTIONS:

How did orientation, duration, and speed affect the path of the Sphero?

How did the scaled drawing help your coding process?

What did you learn from this project?

How well did your group accomplish the assigned task?

How well did your group communicate?

REFLECTION PARAGRAPH:

Write a short connection paragraph connecting things they learned during the MARS and SOLAR SYSTEM activities connecting them back to our MARSBOUND experience and work we've done this term relating to space exploration and STEM.

Figure 7 Journal Activity for reflection and connecting to content (ZOCK, 2019)

Resources

Arizona State University's Mars Education Program, & NASA's Jet Propulsion Laboratory. (2014, April 24). ***Marsbound! Middle School Lesson***. Retrieved March 10, 2019, from https://marsed.asu.edu/lesson_plans/marsbound Copyright 2014; 2012; 2010; 2000.

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NASA Space Place. (n.d.). Retrieved March 11, 2019, from https://spaceplace.nasa.gov/mars-rovers/en/

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NGSS Lead States. 2013***. Next Generation Science Standards: For States, By States.*** (2013). Washington, DC: The National Academies Press. APPENDIX H – Understanding the Scientific Enterprise: The Nature of Science in the Next Generation Science Standards

University of Arizona's Lunar - https://www.uahirise.org/hiwish/maps/dtms.jsp