The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

Traverse the Terrain

The Tech Challenge 2017 Lesson 2: Math
Developed by The Tech Academies of Innovation

I. Lesson Overview

How can you use the coordinate plane to guide a vehicle through uncharted terrain on Mars?

Lesson Description:

During this lesson, students will learn how to create a moving object as well as plot points on a coordinate plane. By creating the vehicle, students will then be able to navigate that device through a map that they create on a coordinate plane.

Grade Levels: 4-8

Education Outcomes:

Students will:

- Plot the locations of vehicles on a coordinate plane.
- Label the points vehicles travel to on a coordinate plane with the correct coordinates (x, y).
- Design and correctly plot hazards on a challenge terrain (coordinate plane) and use coordinates to describe movement through the terrain.

Education Standards

Met: (Note: bolded parts of the standards are fully met by this lesson)

Common Core Standards:

CCSS.5.G.A.2 **Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.**

CCSS.MATH.CONTENT.6.NS.C.8 **Solve real-world and mathematical problems by graphing points in all four quadrants of the coordinate plane.** Include use of coordinates and absolute value to find distances between points with the same first coordinate or the same second coordinate.

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

Addressed: (The following standards are practiced in this lesson but are not explicitly taught and assessed)

Common Core Standards:
CCSS.5.G.A.1 Use a pair of perpendicular number lines, called axes, to define a coordinate system, with the intersection of the lines (the origin) arranged to coincide with the 0 on each line and a given point in the plane located by using an ordered pair of numbers, called its coordinates. Understand that the first number indicates how far to travel from the origin in the direction of one axis, and the second number indicates how far to travel in the direction of the second axis, with the convention that the names of the two axes and the coordinates correspond (e.g., *x*-axis and *x*-coordinate, *y*-axis and *y*-coordinate).

CCSS.MATH.CONTENT.6.NS.C.6
Understand a rational number as a point on the number line. Extend number line diagrams and coordinate axes familiar from previous grades to represent points on the line and in the plane with negative number coordinates.

NGSS Disciplinary Core Ideas (DCI):
ESS3B - Mapping the history of natural hazards in a region, combined with an understanding of related geologic forces can help forecast the locations and likelihoods of future events.

NGSS Science and Engineering Practices (SEP):
Using mathematics and computational thinking:
Grades 3 through 5 - Describe, measure, estimate, and/or graph quantities to address scientific and engineering questions and problems.

Grades 6 through 8: Use mathematical representations to describe and/or support scientific conclusions and design solutions

NGSS Crosscutting Concepts (CCC):
System and System Models : Models can be used to represent systems and their interactions—such as inputs, processes and outputs—and energy, matter, and information flows within systems. Models are limited in that they only represent certain aspects of the system under study.

II. Advanced Prep & Set-Up for Lesson

Get to the Point! Advanced Set-Up

Simple Machines and prior knowledge:

Simple machines should have previously been taught in first lesson in this series (Link to lesson). If students have not learned about simple machines – particularly building a wheel and axle – teach beforehand.

Materials *(per approximately 30 students)*

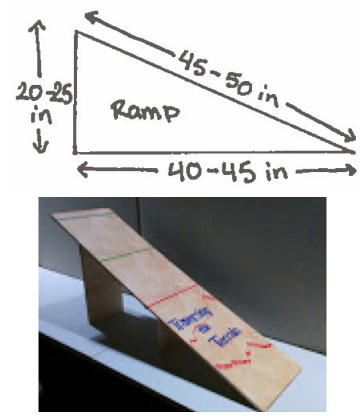
- 8 pre-made vehicles (1 per team of students)*
- Ramp for launching vehicle (see below for specifications)
- 4-6 sheets of grid chart paper, ~~20"x30"

**Students may use vehicles they have already built in a previous lesson (such as "Animal Rescue" [link to ELA lesson]) or use online instructions (see appendix C for resources)*

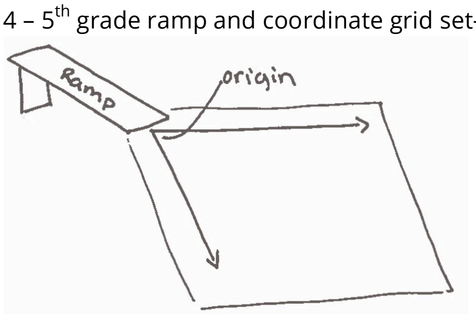
Set-Up

1. Set up a ramp in the middle of the room, visible for all students from their seats.
2. The top of the ramp should be 20-25 inches high with a base of 40-45 inches. And a length of 45-50 inches; this should give you an incline of approximately 25 degrees. Exact measurements are not necessary, as long as all students use the same ramp.
3. [4-5th] The rover will be launched 3 times from 3 different heights on the ramp, with the ramp facing towards Quadrant I, leaving the ramp at the origin.
4. [6-8th] Students will launch their rover 2 times at each height, rotating between the different directions of the ramp, landing at least once in each of Quadrants I-IV of the coordinate plane. The vehicle should leave the ramp at the origin on all launches.
5. As each launch occurs, on their own coordinate grid, students will plot the points at which each of the vehicles come to rest.

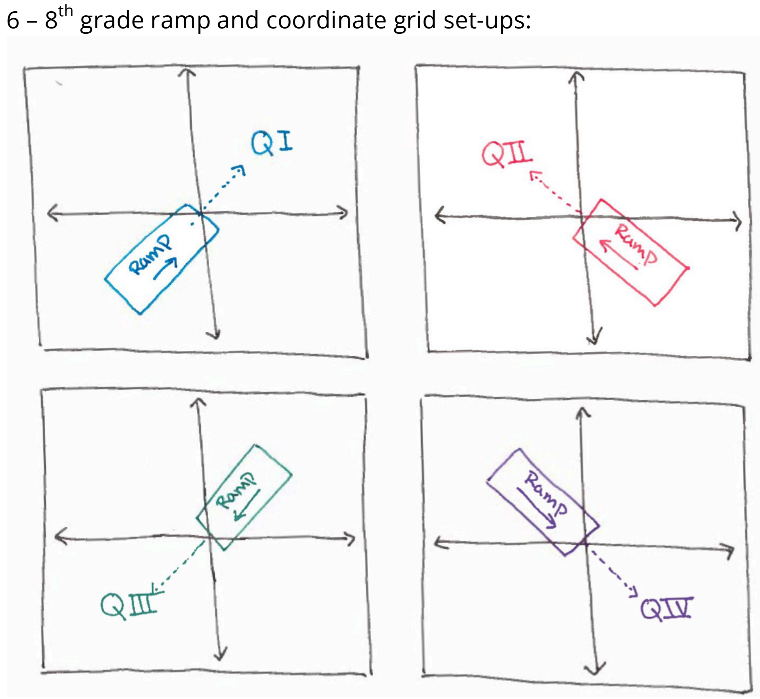
Ramp Dimensions:



4 – 5th grade ramp and coordinate grid set-up:



6 – 8th grade ramp and coordinate grid set-ups:



201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

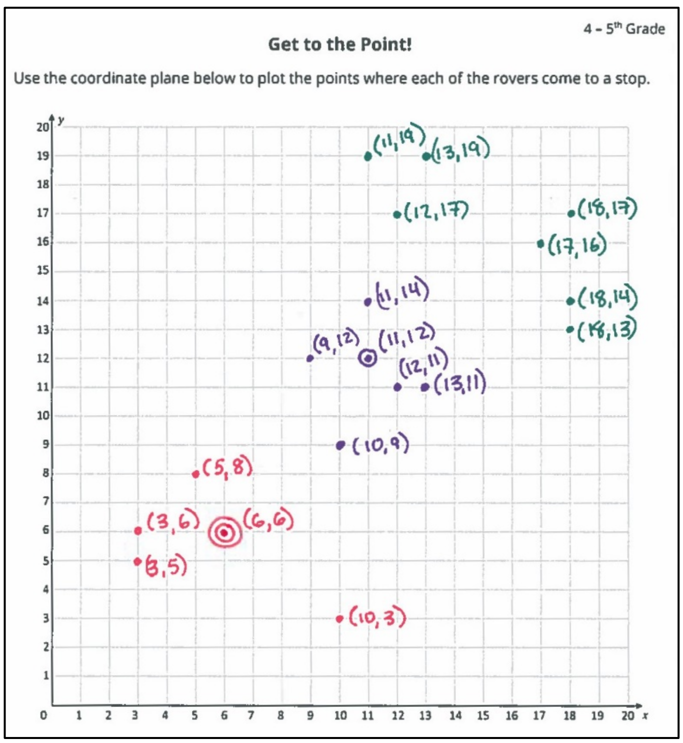
Data Collection

1. Students will take turns launching their rovers onto a terrain (coordinate plane grid) using the ramp launcher. They will have a total of three trials (one trial per height marker on ramp).
2. As students are completing trials, students will plot the resting points on their coordinate plane handout.
3. The class will be recording vehicle resting points together, so all students will end up with a complete visual representation of the vehicles' resting points on a coordinate plane. Students must plot each resting point after each trial. Students will label the resting points based on the height of release of the vehicle: H1, H2, H3. Alternately, If the lines for the different heights of release on the ramp have been color coded, students could color code their points as the plot them on the coordinate plane.
4. Class will record, discuss, and compare the data.

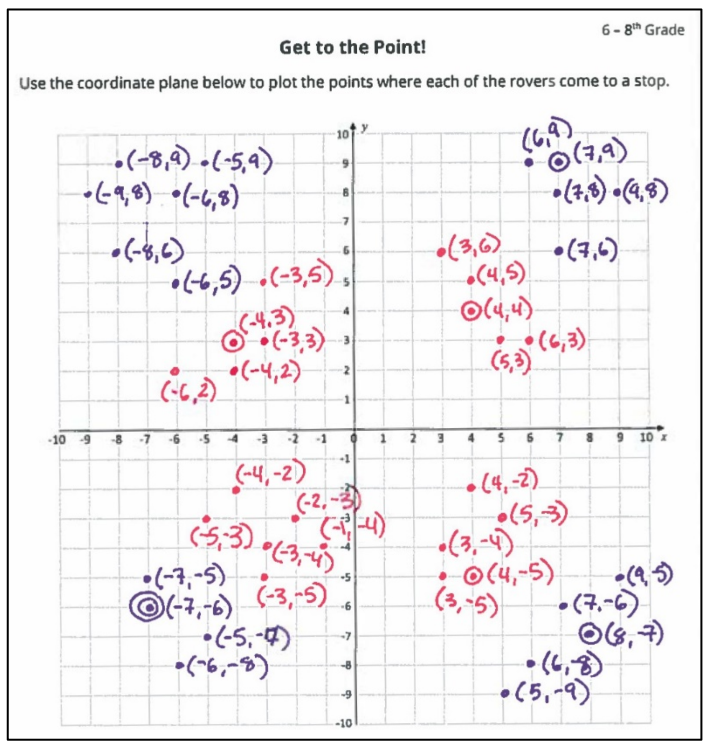
Launching the rover:

The teacher may choose to launch each of the rovers to decrease variability, or can have students launch their own rovers on the ramp.

Sample completed coordinate plane [4 – 5th Grade]:



Sample completed coordinate plane [6 – 8th Grade]:



The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

Traversing the Terrain Advanced Set-Up

Materials *(per approximately 30 students)*

- 8 sheets of grid chart paper (1 per team of students)
- 8 sheets of foam core board or other sturdy board, 20x30" or size of grid chart paper (1 per team of students)
- 8-10 scissors
- 4-8 hot glue guns
- 4-8 rolls of masking tape
- A wide assortment of materials that can be used to build obstacles on the challenge terrain. These could include, but are not limited to:
    - ~~30 pieces of cardboard of various sizes (approximately 5x7" to 10x20")
    - ~~50 jumbo straws
    - ~~50 straws
    - ~~10 round plastic base pieces
    - ~50 #64 rubber bands
    - ~20 corks
    - ~20 dowels, approximately ¼ inch diameter and 5-20" long
    - ~20 square dowels, approximately ¼ inch diameter and 5-20" long
    - ~30 small binder clips
    - ~100 large paper clips
    - ~20 plastic takeout lids
    - 20-40 pieces of foam, assorted sizes
    - ~20 cardboard tubes, approximately 2-4" diameter
    - ~10 cardboard industrial thread spool cones
    - ~10 small pieces of wood (approximately 5x7" or 3x5")

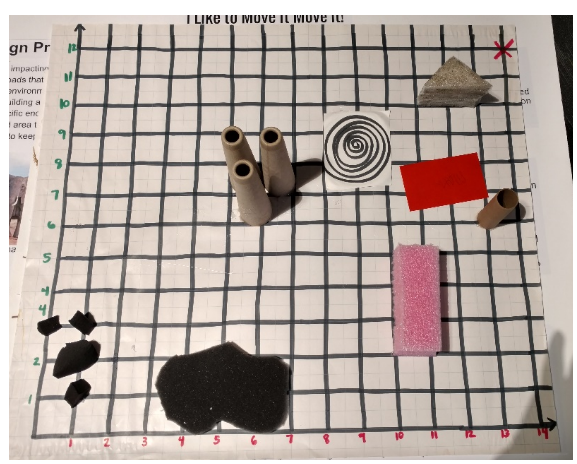
Materials:

It can be helpful to think ahead of time about how student teams will access materials, so as to avoid traffic jams and rushes on the material table. Some ideas include:

- Have each team decide on a materials manager, who will be the only person allowed to gather materials from the materials area.
- Have teams take turns coming up to the materials area, but ensure that there is a limit to what they may take each time, so one team does not end up with all or most of one type of item.

Set-Up

1. Set up the classroom furniture so that students can work in groups of 3 - 4 students around the room.
2. Put the piece of graphing paper in a location where you can use it as an example for students. You may use more than 1 paper to act as the terrain.
3. Model, making the x-y axis and marking the units (2 squares per unit recommended)
4. Place the materials in an area that is accessible by the students. Organize the materials so that it is easy for students to see what is available and how much of each item there is.
5. Give each group of students a large piece of chart paper with grid lines on it. The students have to make an x and y axis on the paper to represent the map of Mars.
6. Students then attach their hazards on the coordinate plane, keeping track of where each of their obstacles are and making directions how to navigate through the terrain (see example of completed terrain to the right).

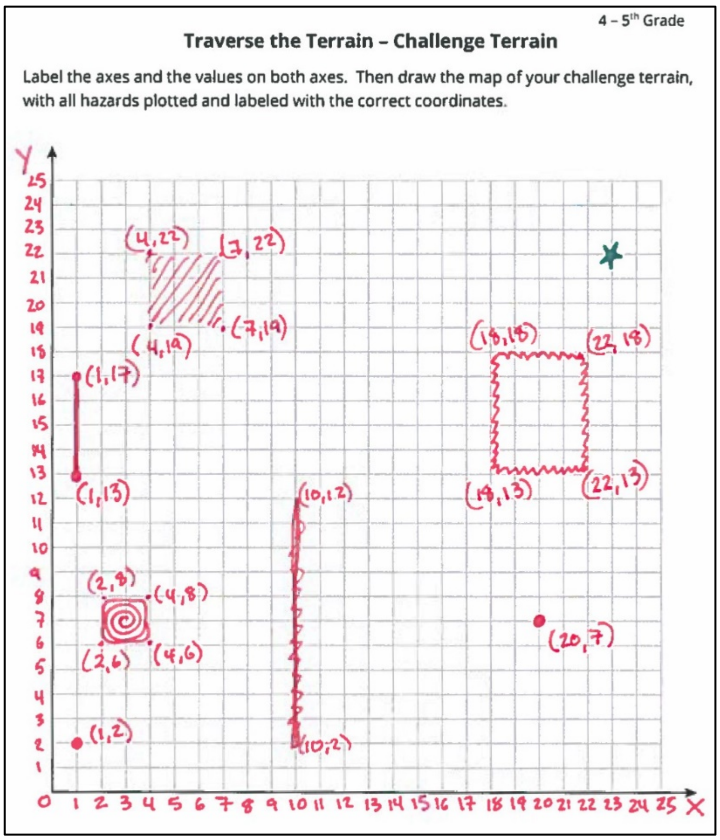


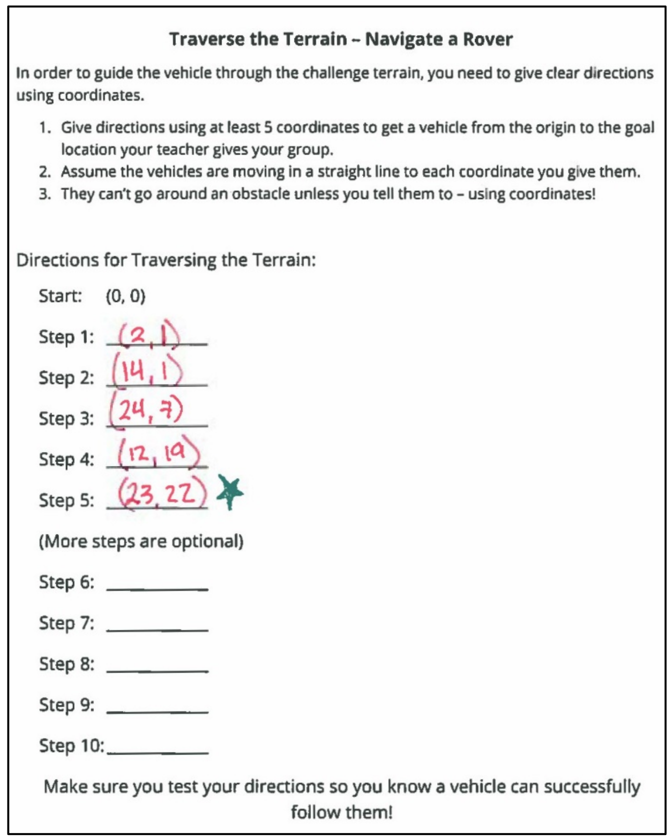
The Tech Museum of Innovation
201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

7. If students want their obstacle to cover multiple points, they have to reference each point of the vertex
8. After hazards are placed and directions written, teams will switch terrains (with directions) and navigate through another team's terrain.

Data Collection

1. While students are working on their terrain, they will be writing down the coordinates of their obstacles.
2. Students should have the table filled out with at least 7 obstacles on their challenge terrain
3. The navigation instructions must have at least 5 steps to get the rover through the terrain safely.





Traverse the Terrain – Navigate a Rover

In order to guide the vehicle through the challenge terrain, you need to give clear directions using coordinates.

1. Give directions using at least 5 coordinates to get a vehicle from the origin to the goal location your teacher gives your group.
2. Assume the vehicles are moving in a straight line to each coordinate you give them.
3. They can't go around an obstacle unless you tell them to – using coordinates!

Directions for Traversing the Terrain:

Start: (0, 0)

Step 1: (2,1)

Step 2: (14,1)

Step 3: (24,7)

Step 4: (12,19)

Step 5: (23,22)

(More steps are optional)

Step 6: ________

Step 7: ________

Step 8: ________

Step 9: ________

Step 10: ________

Make sure you test your directions so you know a vehicle can successfully follow them!

The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

III. Traverse the Terrain Lesson Guide

Guiding Question: How can you use the coordinate plane to guide a vehicle through uncharted terrain on Mars?

A. Introduction (20 minutes)

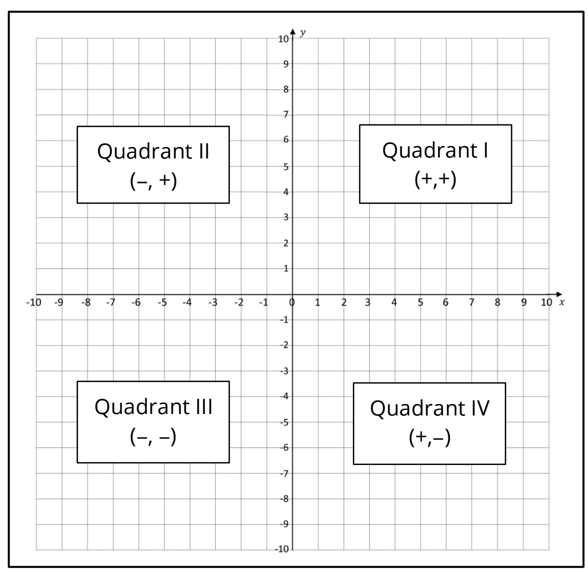
1. Revisit **engineers** and **engineering** with the students to prepare them to think like engineers. Ask students what they know about engineers or engineering:
   - *What is engineering?*
   - *What do engineers do?*
   - Accept all answers as students share their ideas. You may choose to record these ideas on chart paper to look at later. Students may not have much prior knowledge about engineering at this point, but that's ok!
2. Tell students that they are going to be engineers during this project. Help them get excited about what they are going to do! Explain:
   - *We are going to have to think like engineers.* Innovator mindsets are ways in which engineers think and how you think is often more important than what you think.
   - *Let's explore the innovator mindsets that will help us be successful.* Pass out Engineering Design Process Mindsets *(See Appendix D).*
   - With the class go over each mindset (words on the outer gray circle) asking students what they think each mindset means to them.
     - *Open [Be open to all ideas and solutions, listen to everyone's input]*
     - *Playful [Have fun! Wild and crazy ideas are welcome]*
     - *Bold [Take risks, be confident and courageous.]*
     - *Curious [Ask questions, wonder, tinker and ask more questions]*
     - *Perseverance [Failure is the first attempt in learning]*
     - *Collaborative [Work with others to reach common goal]*

> **Innovation:**
>
> Students may already have an idea of what an innovator is, but it may be helpful to discuss with them as you introduce the idea of innovator mindsets and engineering.
> - Innovation is the act of starting something for the first time. Innovation is about creation, new ideas and embracing a growth mindset.

3. Explain to students that they are going to solve a problem as engineers working for NASA.
   - Discuss students' prior knowledge of space exploration, guide the conversation towards exploration of Mars.
   - *What places have humans already explored in space?* [Humans have only physically visited near-Earth orbit and the Moon. We have sent unmanned probes to all of the planets in our solar system, Pluto and many moons. New Horizons is venturing further than any probe thus far exploring the very furthest reaches of our solar system].
   - The Mars Trek Tool, made by NASA, gives anyone the chance to explore land formations on Mars. Students can navigate through Olympus Mons and even follow Curiosity's path through Mars. This is a great resource to allow students to explore independently or as a class, projected on a screen.
   - *Why explore space?* [We explore space for many reasons including: to learn more about ourselves/ the origins of our solar system, Earth and life; and to search for life, which thus far we have only found on Earth.]

- Watch a video, such as "Curiosity Rover Report (August 2015): Three Years on Mars!" with the class and discuss how **rovers** travel on unknown planets. *(See Appendix B)*
- Discuss how scientists at NASA know what the **terrain** of Mars looks like and what **hazards** they have to be prepared to navigate.
  - **terrain**: the physical features of a stretch of land
  - **hazard**: a physical obstacle that can be dangerous
  - *How does a rover know which way to move?*
  - *Who controls the movement of the rover?*
  - *What did you notice about how the rover navigates through hazards?*
  - [Rovers get instructions on movement by radio signal from mission control on earth. Moving safely from rock to rock or location to location is a major challenge because of the communication time delay between Earth and Mars, which is about 20 minutes on average. Unlike a remote controlled car, the drivers of rovers on Mars cannot instantly see what is happening to a rover at any given moment and they cannot send quick commands to prevent the rover from running into a rock or falling off of a cliff. During surface operations on Mars, each rover receives a new set of instructions at the beginning of each sol (Martian day). Sent from the scientists and engineers on Earth, the command sequence tells the rover what targets to go to and what science experiments to perform on Mars.]

4. Introduce the Design Problem students will be working to solve.
   - Tell students that they will be "engineers" and will be designing a test model of (Martian) terrain to help NASA prepare for their next rover mission.
   - How might we use the coordinate plane to guide a rover through Martian Terrain?
5. Explain to the class that in preparation for this big challenge, we will first need to further explore the coordinate system through the Human Coordinates activity.
   - Clear a large space in your classroom, or find an open space outside to facilitate activity.
   - With tape, chalk or another resource, draw a large coordinate plane on the floor.
   - Either have a list of coordinates prepared that you give students one at a time or prepare index cards with coordinates written on them to pass out to each student.
   - Have students stand around the coordinate plane and before you begin playing, review the **coordinate system** with students. Be sure to include the following vocabulary:
     - **axis**: The line on a graph that runs horizontally (left-right) through zero
     - **coordinate**: a set of values that show an exact position
     - **coordinate plane**: The plane containing the "x" axis and "y" axis.
     - **origin**: the point where the x and y axis cross, point (0, 0)
     - [6 – 8th grade: identify **Quadrants I, II, III and IV**]



6. Either by reading them off a list or having students read them from cards you gave them, have students go one by one to a specific coordinate. Remind the class that if someone is struggling in finding the correct coordinate, they may ask for a hint from the class, but

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

everyone should have time to try and find their coordinate on their own before receiving help (no calling out!).

B. Get to the Point! (30 minutes)

1. In this section of the lesson, students will perform an experiment and use the coordinate grid to gather location data about the distances rovers travel. While this is an experiment, the purpose is less about the data that is gathered than it is about the experiences the students have using the coordinate plane and plotting coordinates to show the data.
2. Review with students the concepts and ideas in part A of the lesson. Encourage students to access prior knowledge and repeat what they learned about terrain:
   - *We saw a video of a specific terrain. What does **terrain** mean?* [Terrain is the physical features of a stretch of land.]
   - *What are some adjectives that describe the terrain of Mars?* [Adjectives that can be used to describe the terrain of Mars are dry, mountainous, barren, dusty, rocky, orangey-reddish-brown, etc.]
   - *We noticed that there was special machinery used to traverse, or travel across the terrain. What kinds of machines were used to cross the terrain?*
   - *What are some challenges in crossing this terrain?*
   - *Why do you think these types of machines are used in these types of terrains?* [Special machinery includes **rovers**, which are vehicles used in exploring the tough terrain of a planet. Mars has a challenging terrain because it is rocky, dry, barren, has extreme temperatures, etc. Rovers have the capacity to travel in such difficult areas; therefore, rovers are ideal for these endeavors.]

3. Introduce the "Get to the Point!" & experimental question:
   - *As we discussed in the previous lesson, how do engineers get the vehicle to a specific location?* [Engineers use the coordinate plane to direct vehicles to a specific location].
   - *Today, as engineers, we will be focusing on the terrain of Mars and how engineers locate and direct vehicles there.*
   - Experimental Question: **How does changing the launch height affect the vehicle's resting location on the coordinate plane?**
   - Remind the class that, as engineers, they must conduct experiments to find answers to questions. In this experiment, students will be testing the launch of their rovers from specific heights and determining how this variable (height) affects its resting location on the coordinate plane grid terrain.

4. Discuss the **variables** in the experiment:
   - *A variable is anything that can change during the experiment. In this experiment, we will be focusing on one variable to determine the vehicle's resting location.*
   - *When engineers test a material, scientists conduct a fair test to ensure that everything stays the same except for one condition, or variable, that they are testing – this variable is called the **independent variable**.*
   - *It is important to keep all the other conditions the same so they don't affect the results of the experiment – these conditions are called **controlled variables**.*
   - *What is our independent variable in this experiment?* [Height of the launcher]
   - *How might the independent variable (the height of release on the ramp) affect the resting point location? Why do you say this?* [Accept all answers.]

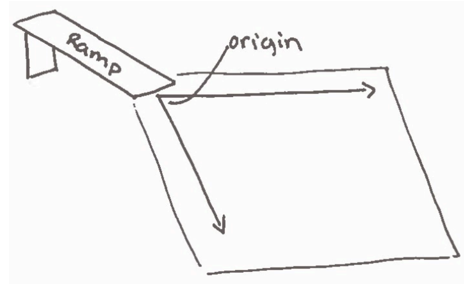
5. Go over experimental question, design criteria, constraints, and testing procedures:

The Tech
Museum of Innovation
201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

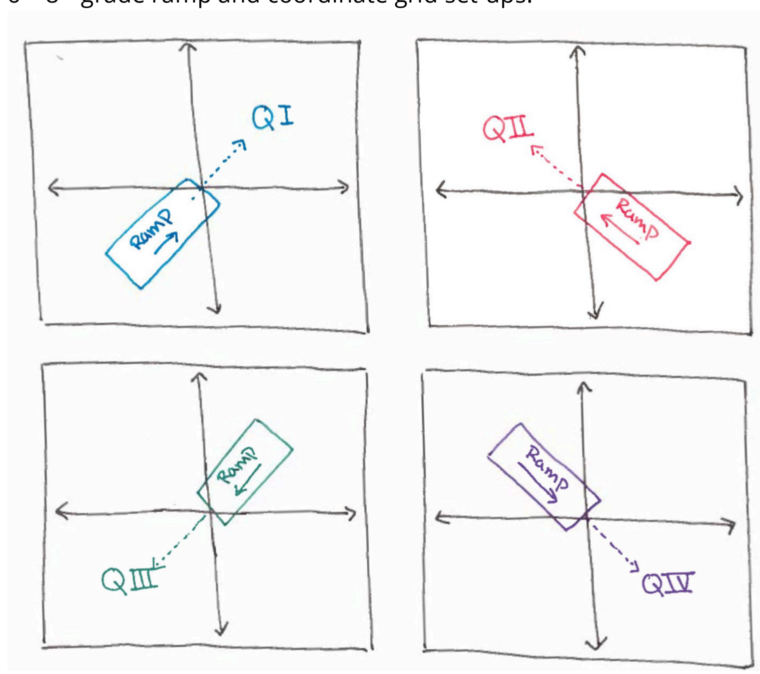
- Students will build a vehicle to go off the ramp that can be used to explore and track the terrain of a new planet for further exploration. The vehicle will be launched on the coordinate plane grid terrain.

- Experimental Question: How does changing the launch height affect the vehicle's resting location on the coordinate plane?
- Controlled variables:
  - All vehicles launched from ramp from three identical heights by release.
  - All vehicles roll (not slide) down ramp
- Independent Variable:
  - Height at which vehicles are launched
- Constraints:
  - Budget: You may only use the materials provided
  - Distance: Vehicles must not roll off the coordinate plane
- Testing:
  - [4-5th] Students will take turns launching their rovers across a terrain (coordinate plane grid). They will have a total of three trials (one trial per height marker on ramp). 4-5th grade uses only a positive coordinate plane, Quadrant I only.
  - [6-8th] Students will launch their rover from all three heights into each quadrant – a total of 12 launches. To do this they will rotate between the different directions of the ramp, but with the bottom of the ramp resting on the origin at all times, so that the rover leaves the ramp at the origin in every launch.
  - As each launch occurs, the students will plot point each of the vehicles come to rest on their own coordinate grid *(see appendix D: "Get to the Point!").*

4 – 5th grade ramp and coordinate grid set-up:



6 – 8th grade ramp and coordinate grid set-ups:



6. Have students share what they think will be the outcome of the experiment.
   - *How do you think height will change the resting point of the vehicles?* [Accept all answers as predictions. Encourage students to support their predictions with prior experience/ prior knowledge]
   - *How will plotting the points on a coordinate plane help us determine the answer to our question?* [Plotting points will give us a picture of how the rovers traveled, and how far they went.]
   - *Why will a coordinate plane be useful as we do the experiment?* [It gives us an organized way to visualize the data we gathered in the experiment.]

7. Lead a discussion with students about the results of the experiment.

- *What did you observe happen during each trial?* [Students should observe the differences in distances the rovers traveled as well as any differences in the paths of the rovers.]
- *Did the vehicles land on the same point?* [The rovers landed on many different points; in general vehicles released from higher points should travel farther.]
- *Why do you think this happened?* [Students may have varied ideas, including that the higher points gave the rovers more energy to travel further distances.]
- *How does the coordinate plane help us gather location information of vehicle resting point?* [The coordinate plane gives us a way to visualize the data and make conclusions based on what we found.]
    - Remember that the intent of the experiment is to familiarize students with the coordinate system and give them experience using it. This experience will give students first-hand understanding of the coordinate system in interpreting and displaying location data.

C. Content Learning (20 minutes)

1. As a class, ensure that everyone has the correct coordinates for all of the points on the map from the *Get to the Point!* Activity (Part B). Be sure to emphasize aspects of the coordinate plane which students may struggle:
    - The horizontal axis is always the x-axis and the vertical axis is always the y-axis.
    - The order in which the coordinates are written is important – (x,y) not (y,x).
    - A set of coordinates is always 2 values, and is plotted as one point, not one point for the x value and one for the y value.
    - Coordinates are always counted from the origin on the coordinate plane.
    - [6-8th] Negative x coordinates are to the left of the origin and negative y coordinates are below the origin.

2. Now that students have a map of location data for their rovers from the previous activity, connect this activity with the importance of coordinate graphing for scientists and especially in relation to our big problem.
    - Explain to students that, as engineers and scientists, we all need to be able to communicate results to others. Ask students how they would tell others their data about rover locations without drawing the map.
        - *How could you tell other engineers where the rovers traveled to?* [Answers will vary.]
        - *What kind of information would engineers need to be able to make an identical map?* [Students may come up with different methods. One might include: you could tell them how far over and how far up the points were and then what team's rover was at that point.]
        - [6-8th – all 4 quadrants) Students may come up with different methods. One might include: you could tell them the locations of points by giving them positive or negative numbers that tell how far to the left or right of the x-axis each point was and how far above or below the y-axis each point was.]

> **Older grades:**
>
> With 6th – 8th grade students, they may make the connection to coordinates and the coordinate plane themselves because they have had more experience with the coordinate system than younger grades. If this happens, lead a discussion about the more difficult aspects of the coordinate system that are introduced in the middle school grades – quadrants II, III, and IV; negative movement from the origin; translating word problems or verbal terms to the coordinate plane.

3. Have students demonstrate their thinking with 1 or 2 of the points on the map.

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

- Connect what students are doing to the idea of coordinates within a coordinate system. Help students remember what they know about the coordinate plane by using their experience in *Get to the Point!:*
  - The origin is where the ramp ended, where the rovers came off the ramp and started their travel on the coordinate grid.
  - The x-axis coordinate is always the first one and the y-axis coordinate is always second in an ordered pair. Travel across and then up when finding a coordinate on the coordinate plane – you have to run before you can rise!

4. Have students complete the back of the worksheet *(see appendix D: "Get to the Point!")* with their explanation of how to find coordinates on a grid as well as how to plot a point on a coordinate grid when given the coordinates.
   - As a class, come up with an agreed upon process for plotting a point on the coordinate plane. It may be helpful to post these steps on the board or wall using chart paper for students to reference throughout lesson and activity. For example:
     1. Identify the x and y values in the given coordinate.
     2. Start at the origin (0, 0)
     3. Move the value of the x coordinate along the x axis [6-8th positive numbers to the right, negative to the left]
     4. Starting where you stopped on the x axis, move the value of the y coordinate vertically [positive numbers up, negative numbers down]
     5. Mark the point, this is the location of the coordinate.

D. Traversing the Terrain (50 minutes)

Research and Background Knowledge:

This may be an opportunity to incorporate research skills in the process. Students may spend some time researching the terrain of Mars and the obstacles or hazards a rover might encounter while travelling across the terrain.

1. Review the final Engineering Design Challenge
   - Review the real world problem that you are addressing: NASA needs a Mars Testing Yard to test and collect data on new Mars Vehicles. Have a discussion with students about what obstacles would be encountered if a rover were on Mars and how the vehicle would avoid them.
     - *If the vehicle you built was on Mars, what are some of the obstacles it would encounter?* [craters, cliffs, cracks and jagged boulders]
     - *What are ways that you might represent the various obstacles and hazards on the terrain?* [Answers will vary depending on the materials available]
     - *What are ways that your rover can avoid challenges on the terrain?* [Rovers can move around the obstacles on the sides by changing the direction they travel]
     - *How would we represent these hazards in the testing yard and what analogs might we use for different types of terrain?* [Answers will vary depending on materials available but could include sandpaper for rough ground, cotton balls for sandy area, boxes for cliffs, etc.]
   - Explain to students that they will work with their group to create a terrain with obstacles on a coordinate plane for their rovers to traverse. After they have explored their own terrain, they will trade with another group to navigate that group's terrain using the written instructions the group has created.
   - The coordinate grid they use for this activity represents the range of communication for the rover.
     - *The rovers used on Mars do not have infinite range when it comes to communicating with the base.*
     - *Engineers need to make sure that they keep that in mind when they are testing rovers in a challenge terrain, so they set limits for the distance a rover can travel as a way to model these limitations.*

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

  - *In order to stay in contact with their navigational equipment, the rover must stay in the boundary of their coordinate grid, or it will lose communication and be lost forever!*
- See instructions in the set-up descriptions (Part II, "Advanced Prep & Set-Up for Lesson") for preparing for this activity.

2. Go over the design challenge with students:

Design Problem:
- As scientists, you must construct a physical model (a "challenge terrain") to test a Mars vehicle so that it will be able to travel where we need it to go on Mars. The ground team also needs to correctly communicate the locations of hazards that must be avoided to navigate the new terrain via written instructions.

Criteria (Design Requirements/Desired Features):
- The challenge terrain must
  - be built on a coordinate plane (x and y axes) on graph chart paper with the axes and values correctly labeled
  - [4-5th] include at least seven hazards
  - [6-8th] include at least ten hazards, with at least one in each of the four quadrants
- The hazards of the challenge terrain must be correctly plotted on the data sheet *(see appendix D: "Traverse the Terrain – Challenge Terrain")*
- The written instructions to safely navigate the challenge terrain must include at least five coordinates between which the rover moves in straight lines, and must get the vehicle safely from the origin to the point designated by the teacher.
- A provided Mars test vehicle must be used.

Developing Criteria and Constraints:

For 6th through 8th grade students who are developing their critical thinking skills, the teacher may lead a class discussion allowing students to set the criteria and constraints. For more detailed instruction see Background Information *(see Appendix B).*

Rovers:

Decide if students will be using the same rovers they built for *Get to the Point!* (Part B) or if students will build new rovers. In addition, other vehicles may be a stand-in here for the rover, such as toy cars, board game pieces, etc.

Constraints:
- Budget: Challenge terrain must be completed only with materials provided.
- Schedule: Challenge terrain must be completed in 30 minutes.
- Rover communication: Challenge terrain must stay on the coordinate plane so that the rover stays within range of communication with the base.

Testing:
- You will design the testing parameters as a class, see #3 below.

3. Help students to develop their skills in designing fair tests by facilitating a class discussion on a test design. Guide the class in planning out how they will test their challenge terrain. Some questions to use when guiding the discussion could include:
- *What would success look like for this design problem?* [A challenge terrain that meets the criteria with instructions that safely get another team through the hazards. Students may want to talk about how quickly another team can get through the hazards safely, how creative the hazards that are designed are, or other aspects of solutions to the design problem.]

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

- *How will we measure success? How will we know if a design is successful?* [Suggestions may include having teams observe each other and judge how well instructions help the rover to navigate around hazards, having teams check each other's maps to make sure the hazards are correctly plotted, or other ideas. Try to help students find ways to measure *each other's* success and not have the teacher grade it!]
- *How will we identify failure points of the designs?* [Students may give similar responses as the previous question. Examples of failure points for this challenge might include the use of too many obstacles so that there is no way for a vehicle to get through the testing yard. The other side of the spectrum might be the inclusion of too few obstacles to make a realistic test yard. A failure point could also be miscommunication of location of obstacles causing a rover to run into an obstacle.]
- *What data will the class record during testing?* [In some ways, the navigating of a rover through a challenge terrain based on the team's instructions is the data itself, but students might also think of ways to keep track of successful 'missions' through challenge terrains, or by grading each other's maps or instructions.]

4. While the students are working on their designs (challenge terrains), walk around and ask questions to facilitate the teams' work and creative problem solving. Some suggested questions are:
   - *What materials did you choose? Why?*
   - *What does this object represent?*
   - *What are the coordinates of this obstacle?*
   - *How is the x-axis related to the y-axis?*
   - *How many units does each line on your x- and y- axis represent?*
   - *Can you elaborate on the reason that you put your obstacles where you did?*

5. After each team has designed and tested their challenge terrain, it is time for teams to trade terrains with another team to navigate *(see appendix D: "Traverse the Terrain – Navigate a Rover")*.
   - *To test our terrains, we are going to challenge other teams to use the instructions you have written to safely navigate their rover through your challenge terrain while safely avoiding the hazards.*
   - *Remember that your navigation instructions must be clear enough that the person 'driving' the rover can follow them by simply being given the coordinates to direct the rover's movement.*
   - Students switch challenge terrains (the obstacles should be taped/glued well enough to move it without it falling apart)
   - Each group will get written directions from the group that they traded with, detailing the route (using coordinates) to navigate the terrain.
   - The students will physically guide their vehicle through the terrain based upon the points that the other group wrote down. To simulate how NASA communicates with rovers, one member of the team will sit with their back to the terrain, and read the coordinates in the instructions one by one, as another team member moves the rover in straight lines to each coordinate.
   - The remaining team members act as data analysts to note any failure points in the navigation instructions.
     - If the team finds any failure points, they should work as a team to correct the navigation instructions so the rover can move safely through the terrain. It may help to have students write corrections in another color pen or marker so the original instructions are still legible.
6. After the students navigate another group's terrain, come together as a whole class to discuss.
   - *What was challenging about navigating your team's terrain?*
   - *What changes (iterations) did you make to improve your process?*

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

- *If you had more time and resources, how would you improve your design to make it easier to navigate through challenging terrain?* [Accept all responses. Emphasize the importance of learning from failure to constantly improve designs.]

7. After seeing all the devices demonstrated and discussing their different aspects, lead the class in a discussion about the different uses of each of the different rovers and terrains.
   - *How do we give/use directions on Earth?* [Usually this happens when people can see each other or receive feedback in real time. Students are probably familiar with how navigation on a cell phone or a car's navigation system works, and can explain how the navigator knows immediately if you are on the right track or not.]
   - *How might that be different in outer space?* [People on the ground can't see what is happening as the directions are being followed, so it is not always clear if your instructions are working. There is also a delay between when we send a radio signal to Mars and when the rover actually receives it.]
   - *How does using a coordinate plane help us in real life?* [It gives everyone an identical reference for understanding locations in relation to each other and direction of travel.]
   - *What are some situations in which a coordinate plane would be useful?* [Answers will vary, but may include directions on a map, scavenger hunts, locating buried treasure, knowing locations of buried hazards like water pipes and electrical wires, etc.]

E. Evaluation (20 minutes)

Formative assessments and evaluation of student learning is integrated throughout the lesson. This section summarizes suggestions for implementing summative evaluations, as well as creating authentic experiences for the students around the design challenges and their learning by making work public.

Having students participate in an authentic presentation or discussion of their work is a great way to reinforce the idea that they too are engineers, and that their work should be shared with community and the public in similar ways. Finding some way to bring students' work to a larger audience also helps to build on the idea that engineers help people in creative ways and are part of something larger than themselves.

1. Review the rubric with students at the introduction of the project so they know what their learning goals are *(see appendix D: "Traverse the Terrain Rubric")*. It is important to allow students to "begin with the end in mind," just as teachers backwards plan, using standards and assessments to inform units, topics, and day-to-day activities.

2. The rubric included in this lesson guide is designed to evaluate student mastery of the "met" standards using the categories *Below Standard, Approaching Standard, Meeting Standard,* and *Above Standard.* This allows teachers to give individual feedback particularly for the students who are Below Standards or Above Standard in particular areas.

What are we assessing?

Remember that students are not being graded on whether or not their design was successful in meeting all the criteria and constraints of the design challenge. The important part of design challenge learning is the process, and helping students develop their skills in working through difficult problems and persevering through failure.

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

- In the Below Standards and Above Standards sections of the rubric, the idea is that no student should be receiving these scores without personalized attention from the teacher – either as remediation or as extension to reach students where they are.
- With that in mind, the descriptions and observations in these two sections are simply examples of what you *might* see for students performing at that level. The comments and notes in these sections should be tailored to the specific student and should accompany individualized support and conversations.

3. At the end of a project or design sequence, engineers (and indeed all scientists) share their work with an audience, whether that is the client or other stakeholders. For students, this type of presentation is just as important. Connecting students with an authentic audience is key to driving engagement and helping students relate what they are learning to the real world. Our goal here is to ensure that our budding engineers feel the interconnectedness of what they are doing and experience the "why" behind problem solving.
   - Some ways to do this are:
     - A mini conference
     - A panel
     - Teach back to younger students
     - Recommendations/ proposal to important constituents
     - A letter to the editor
     - A multimedia presentation to post on the Internet
   - Think through what you want students to gain from the interaction:
     - If it's technical feedback, think about inviting experts for a pitch session or judging panel
     - If it's response or action, think about having students make presentations to a community group or decision-making body (such as a school board, city council, or neighborhood association)
     - If it's a celebration, think about inviting community members whose talents or contributions are being honored or recognized in student projects
   - Try to connect to who the audience would be for the "real-world" version:
     - If students are producing documentaries, plan a red carpet screening event
     - If students are making sense of history, set up a museum-style exhibition
     - If students are producing literature, plan a book release party, author chat, or poetry slam

4. When students have completed the design challenge and have reflected as a class, remind them that they will be completing self-reflections on how they did throughout the design challenge and the design process *(see appendix D "Reflecting on the Design Challenge"):*. Review the parts of the self-reflection with them, and remind them that reflection is part of the process and is how we improve. Just like during the engineering process, we have to be honest with ourselves and others about what went well and what we still need to improve.

The Tech
Museum of Innovation
201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

IV. Appendices

A. Vocabulary

The following is the start of a suggested list of words to discuss as you read and discuss with students.

Term	**Student-friendly definition**
acceleration	increase in the rate or speed of something
axle	A bar that is connected to the center opening of a wheel and allows it to turn
chasm	a deep hole or opening in the surface of the earth
constraint	the limitations of a design problem which typically include budget and schedule limitations but may also include other limitations such as maximum size restrictions
coordinate axis	Consists of two mutually perpendicular axes that intersect at the origin (0,0).
coordinate plane	Is determined by horizontal line (x) and a vertical line (y) and the intersection of these (origin)
criteria	the requirements or desired features of a design problem often describing the purpose and standards that a system or device must meet
design problem	The identified challenge, goals, or needs that a design addresses. What you are trying to solve.
design process	A series of steps that engineers use to guide them as they solve problems. The process is nonlinear but cyclical, meaning that engineers repeat the steps as many times as needed, making improvements along the way of imagining, creating, reflecting, testing and iterating. These are steps used to come up with solutions: [design process graphic goes here]
dynamic	Always active or changing
engineer	A person who designs and builds innovative solutions (machines, systems, or structures) to solve a problem or meet a need
engineering	The process that engineers go through to create, design, test, and build a solution
failure point	A place where the design or system failed
function	The action or purpose of an object including how it moves or interacts with other objects
hazard	Any source of potential damage, harm or adverse health effects on something or someone under certain conditions
integer	A whole number that is not a fraction

The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

iteration	When you try different solutions (create, test, reflect, imagine) over and over
load	Another word for force, or what the structure has to hold up to; in a machine doing work, like simple machines, a load is the weight or mass being supported and/or moved
model	A representation that scientists use t0 replicate and understand a concept
negative(6th - 8th)	A characteristic of numbers whose values are less than zero
optimal design	The design or device that best meets the criteria and constraints
positive(6th - 8th)	A characteristic of numbers whose values are more than zero
prototype	The models that you build to test before you get to your final solution
rover	An automated motor vehicle that propels itself across the surface of the planet Mars
simple machine	Basic mechanical devices for applying force: inclined plane, wedge, lever, wheel and axle, pulley, screw
static	No movement, action, or change
structure	The material or arrangement of parts in an object to make up the whole
terrain	The physical features of a stretch of land
trade-off	A situation in which you must choose between or balance two things that are opposite or cannot be had at the same time
wheel	A circular object that revolves around an axle

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

B. Resources and Background Information

Resources:

- Buzzle, Simple Machines – Background information on simple machines including facts, history, and working mechanisms. http://www.buzzle.com/articles/simple-machines/

- *Curiosity Rover Report (August 2015): Three Years on Mars!* A video from NASA that explains what the Curiosity rover accomplished in its first three years on Mars, and what is next: https://www.youtube.com/watch?v=Txti0XLxOzI

- Dirtmeister's Science Reporters – A student-friendly website that explains simple machines and how they work. http://teacher.scholastic.com/dirtrep/simple/invest.htm

- Engineer Your Life – A guide to engineering for high school girls and information from studies of girls and their engineering interests. http://www.engineeryourlife.org/cms/engineers.aspx?subpage=8765

- Make a Toy Car – WikiHow instructions for making a variety of cars from every day materials: http://www.wikihow.com/Make-a-Toy-Car

- Mars Exploration by NASA: This website is full of fun facts and interactive tools centered around Mars Exploration designed just for kids: http://mars.jpl.nasa.gov/participate/funzone/

- "Mars Exploration Rover Mission: The Mission". *Mars.nasa.gov*. N.p., 2016. Web. 13 Oct. 2016. http://mars.nasa.gov/mer/mission/tl_surface_sci.html

- Mars Trek Tool by NASA: This gives anyone the chance to explore land formations on Mars, you can navigate through Olympus Mons and even follow Curiosity's path through Mars. http://marstrek.jpl.nasa.gov/

- *Mission: Mars* by Pascal Lee: This book aims to inspire the next generation of astronauts who will be the first humans to visit Mars. [Lee, Pascal. *Mission: Mars*. Scholastic, 2013. Print.]

- NASA Quest: A great place to find a lot of free online tools and resources for teachers, students, parents this link explains to the reader how models are developed and used by engineers: http://www.quest.nasa.gov/challenges/marsanalog/background.html

- Roving on the Moon: PBS Kids Design Squad activity on building a rover that can travel across the room: http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_NASA_05Roving_LN_CS.pdf

- Rubber Band Car: PBS Kids Design Squad activity on building a rubber band powered car: http://pbskids.org/designsquad/parentseducators/resources/rubber_band_car.html

- Science Trek Simple Machines Facts – A student-friendly website that explains simple machines, how they work, and gives history of each one. http://idahoptv.org/sciencetrek/topics/simple_machines/facts.cfm

- The Tech Museum of Innovation, Design Challenge Learning – A resource for background information on Design Challenge Learning as well as multiple lessons for a variety of age ranges and content areas. http://www.thetech.org/educators/design-challenge-learning

The Tech
Museum of Innovation
201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

Background Information:

Simple Machines:

Explain to students that as mechanical engineers, they must use their scientific eyes to carefully observe **simple machines.** Class will come up with an observation list. This will enable students to start thinking about how they notice simple machinery at work.

- *We noticed rover(s) crossing the terrain. Rovers are designed to cross terrains that can be very challenging. Based on your observations, what are some characteristics of a rover? What does it look like? How do these machines move?*
- Students should note that rovers have x number of wheels, x type of shape, etc. Answers may vary, but students should notice that there are 4 wheels for stability and that each pair of wheels is connected by an axle.
- The class will be focusing on a specific aspect of the function of the rover: the rolling. *What makes the rover roll? How do these wheels actually move?*

Review simple machines: **wheel and axle**

- Organize students into groups of 3-4. Hand students black box. Inside the black box, place a small toy or device that requires the use of a wheel and axle. Students will play with these items, noting the function and structure of the wheel and axle.
- *Now, as engineers, we are going to explore simple machines. Let us focus on a simple machine called wheel and axle. In your boxes, you have an item. Observe your [toy]. How does it move? What allows it to roll? What makes it work? Take 3 minutes to observe and write down your observations.*
- Project a visual of a wheel and axle. Allow 2-3 students to share their observations out-loud addressing the previous questions:
  - *How does it move? What allows it to roll? What makes it work?* [Students should notice that the wheel is attached to a "rod" or "stick" that spins freely allowing the wheel to turn easily.]
- Explain the logistics of the wheel and axle. The wheel and axle machine works when a circular object--called a wheel--and a shaft--known as an axle--are attached. The wheel and axle work by reducing the effect of **friction** on an object.
  - *We call the "rod" or "stick" an "**axle**." Instead of sliding across the ground, the wheel turns, so there is less resistance or "**friction**" from the ground allowing it to move more easily.*
  - Model this by holding up one of the toys and asking students how the toy's movement would differ if it did not have wheels. Student answers should explain the aforementioned logistics.

Creating Criteria and Constraints as a class

[6-8th] As middle school students develop their skills in defining the problem, guide them in a group decision-making process of the criteria and constraints for the design problem.

- Ask students to think about the design problem with their teams*. How will they know if a design is successful? Specifically students should decide:*
  - *How will we know where each obstacle is on the challenge terrain?*
  - *What kind of constraints need to be in place (radio contact) in order for a successful navigation of the terrain?*

The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

- After teams have discussed in small groups, have the class come together and lead a discussion to come to consensus on the criteria and constraints for this design problem.
- Students should develop a drawing of what they want their grid/terrain to look like before creating the full size terrain.

The Engineering Design Process:

Introduce the engineering design process graphic with students to show how engineers engage in fun, creative, problem-solving that is core to their work.

- Explain to students that as engineers go about solving problems and coming up with creative and innovative solutions to challenges, they follow the **design process.**
  - **Design Process**: a series of steps that engineers use to guide them as they solve problems. The process is non-linear but cyclical, meaning that engineers can follow the steps in no particular order, repeat the steps as many times as needed, and make improvements along the way of imagining, creating, reflecting, testing and iterating.
- We represent this process with a graphic that shows the main steps someone goes through as they solve a problem.
  - Define your problem: What is the problem you are trying to solve? What are the **criteria** (design requirements that will determine the success of your solution)? What are the **constraints** (real-life limitations like budget and schedule) that you have to work within?
  - Test/reflect – imagine – create: This is the main part of the process that is cyclical. This is where engineers go through multiple designs as they have ideas, try something out, test it, have new ideas, and incorporate it all into more building and testing. This process can go through many rounds as an engineer gets more information from each test and design that is tried.
  - Share your solution: Engineering is about teamwork, and engineers frequently learn from each other as they solve problems. It's important for students to communicate and share throughout the process so that just like real engineers, they can learn from each other and improve their solutions. It's particularly important to culminate a project with a formal sharing of solutions and perhaps even a showcase or other authentic way to share lessons learned with the broader community (e.g. community members, family members, principal, younger students etc.)
- When you see the design process in action, you'll notice that it's rarely the smooth succession of steps that the diagram implies. The steps often overlap and blur, and their order is sometimes reversed—it's a creative, fluid way of working that has to be adapted to each individual situation.
- As you guide students through the design process, you'll want to be flexible and receptive to the different approaches your students may try.
- Ask students to notice where they are in the design process and even to trace their path through the steps, so they can see how messy it can be.

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

Failure

One important aspect about engineering that is vital to how engineers solve problems is the importance of failure to learn and improve solutions.

- As engineers work on creating solutions and improvements, it is important to remember that failure is not only part of the process, it is necessary in order to improve and find success.
- Every time an engineer fails to solve a problem completely, s/he learns a new piece of information about how the design functions and how to make it better.
- When engineers find a part of the design that doesn't work, it is called a **failure point**.
    - A **failure point** is a design element that can cause an unsuccessful result. This is the point in a system that if it fails, the whole system fails.
- It is important to celebrate the failures that students may experience during the design process. Instead of "Oh no, that doesn't work!" try
    - *Now you know what happens when you try that! You have more information!*
    - *What did you learn from that?*
    - *What will you try next to improve your design?*
- Failure is an important part of the design process and should be celebrated as a positive way to learn. It is important to remind students that there is no single "right" answer in engineering; one problem can have many solutions.

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

C. References

- Buzzle, Simple Machines – Background information on simple machines including facts, history, and working mechanisms. http://www.buzzle.com/articles/simple-machines/
- "Coordinate Axes." *Coordinate Axes*. Ditutor.com, 2015. Web. 29 July 2016.
- "Coordinate Plane Grid". *Math Salamanders*. N.p., 2016. Web. 13 Oct. 2016. http://www.math-salamanders.com/coordinate-plane-grid.html
- "Curiosity Rover Report (August 2015): Three Years On Mars!". *YouTube*. N.p., 2016. Web. 13 Oct. 2016. https://www.youtube.com/watch?v=Txti0XLxOzI
- "Design Challenge Learning". *The Tech Museum of Innovation*. N.p., 2015. Web. 13 Oct. 2016. http://www.thetech.org/educators/design-challenge-learning
- "Dirtmeister: Simple Machines -- Investigate The Facts". *Teacher.scholastic.com*. N.p., 2016. Web. 13 Oct. 2016. http://teacher.scholastic.com/dirtrep/simple/invest.htm
- "Engineer Your Life - Engineers". *Engineeryourlife.org*. N.p., 2016. Web. 13 Oct. 2016. http://www.engineeryourlife.org/cms/engineers.aspx?subpage=8765
- "How To Make A Toy Car". *wikiHow*. N.p., 2016. Web. 13 Oct. 2016. http://www.wikihow.com/Make-a-Toy-Car
- Lee, Pascal. *Mission: Mars*. Scholastic, 2013. Print.
- "Mars For Kids". *Mars.jpl.nasa.gov*. N.p., 2016. Web. 13 Oct. 2016. http://mars.jpl.nasa.gov/participate/funzone/
- "Mars Exploration Rover Mission: The Mission". *Mars.nasa.gov*. N.p., 2016. Web. 13 Oct. 2016. http://mars.nasa.gov/mer/mission/tl_surface_sci.html
- "Mars Trek". *Marstrek.jpl.nasa.gov*. N.p., 2016. Web. 13 Oct. 2016. http://marstrek.jpl.nasa.gov/
- "Rubber Band Car . DESIGN SQUAD GLOBAL | PBS KIDS". *Pbskids.org*. N.p., 2016. Web. 13 Oct. 2016. http://pbskids.org/designsquad/parentseducators/resources/rubber_band_car.html
- "Simple Machines: Facts (Science Trek: Idaho Public Television)". *Idahoptv.org*. N.p., 2016. Web. 13 Oct. 2016. http://idahoptv.org/sciencetrek/topics/simple_machines/facts.cfm
- "Welcome To NASA Quest!". *Quest.nasa.gov*. N.p., 2016. Web. 13 Oct. 2016. http://www.quest.nasa.gov/challenges/marsanalog/background.html
- WGBH Educational Foundation,. *Roving On The Moon*. Design Squad TM, 2008. Print. http://www-tc.pbskids.org/designsquad/pdf/parentseducators/DS_NASA_05Roving_LN_CS.pdf

The Tech
Museum of Innovation

201 S. Market St.
San Jose CA. 95113
1-408-294-8324
thetech.org

D. Lesson Handouts

Name: ______________________________

Date: ___________ Class: ______________

Engineering Design Process and Innovator Mindsets

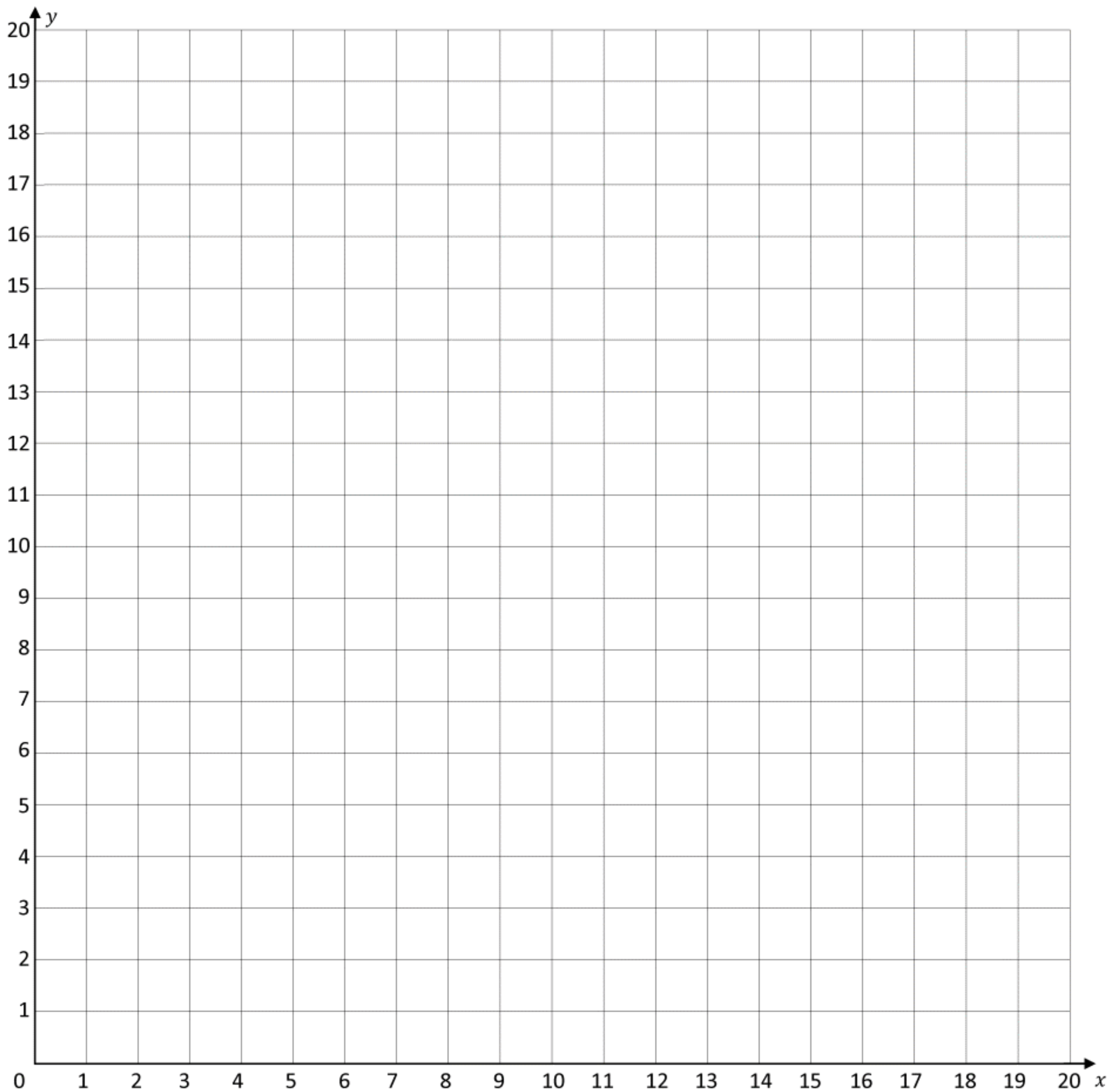
Name: ______________________________

Date: ___________ Class: _______________

4 – 5th Grade

Get to the Point!

Use the coordinate plane below to plot the points where each of the rovers come to a stop.



Name: ______________________________

Date: __________ Class: ______________

Explain how to find the coordinates of a point on a coordinate grid. You can draw a diagram and use that to guide your explanation if that is helpful.

Explain how to plot a set of coordinates you are given on a coordinate grid.

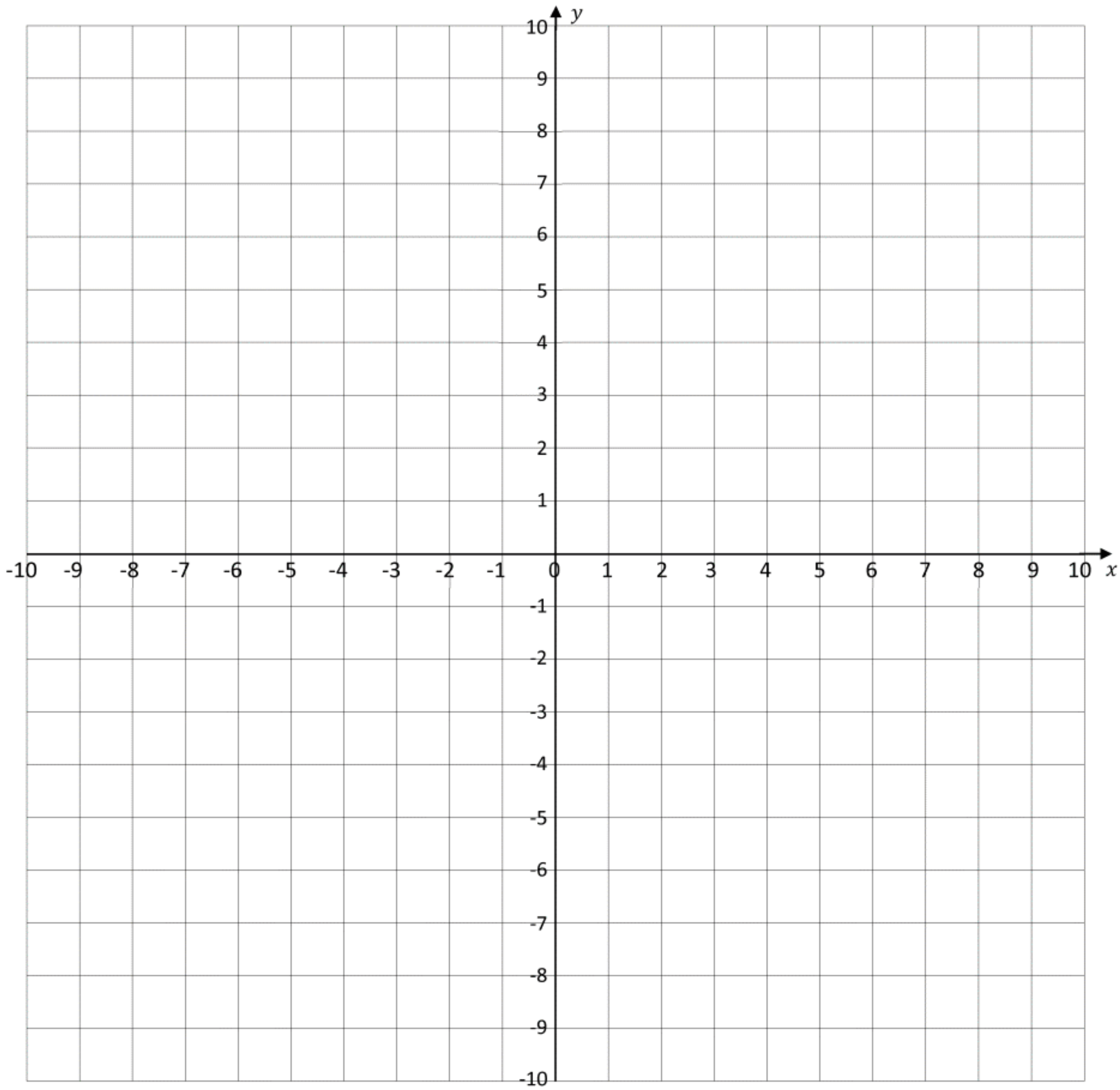
Name: ______________________________

Date: __________ Class: ______________

6 – 8th Grade

Get to the Point!

Use the coordinate plane below to plot the points where each of the rovers come to a stop.



Name: ______________________________

Date: ____________ Class: ______________

Explain how to find the coordinates of a point on a coordinate grid. You can draw a diagram and use that to guide your explanation if that is helpful.

Explain how to plot a set of coordinates you are given on a coordinate grid.

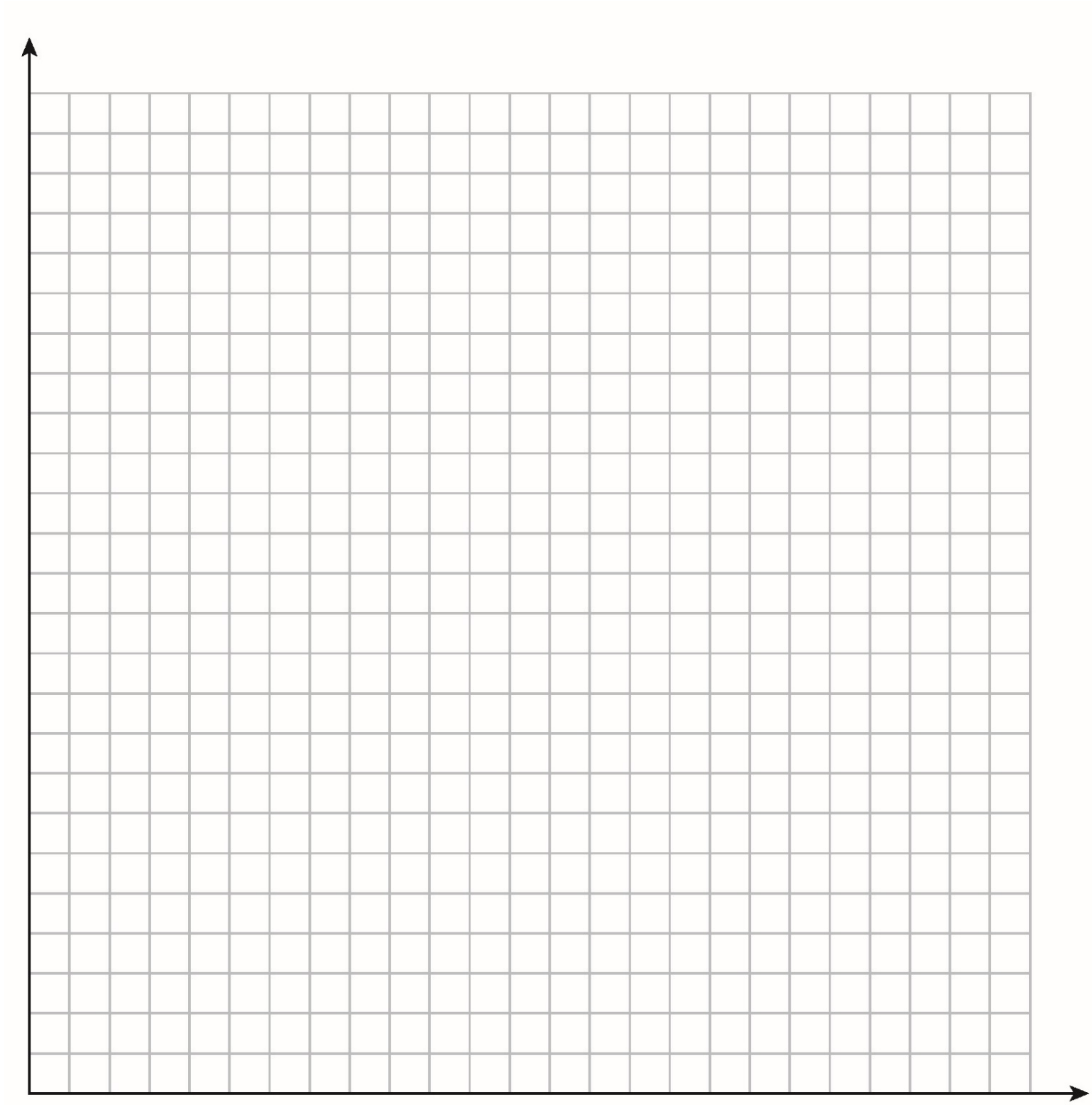
Name: ______________________________

Date: ___________ Class: _______________

4 – 5th Grade

Traverse the Terrain – Challenge Terrain

Label the axes and the values on both axes. Then draw the map of your challenge terrain, with all hazards plotted and labeled with the correct coordinates.



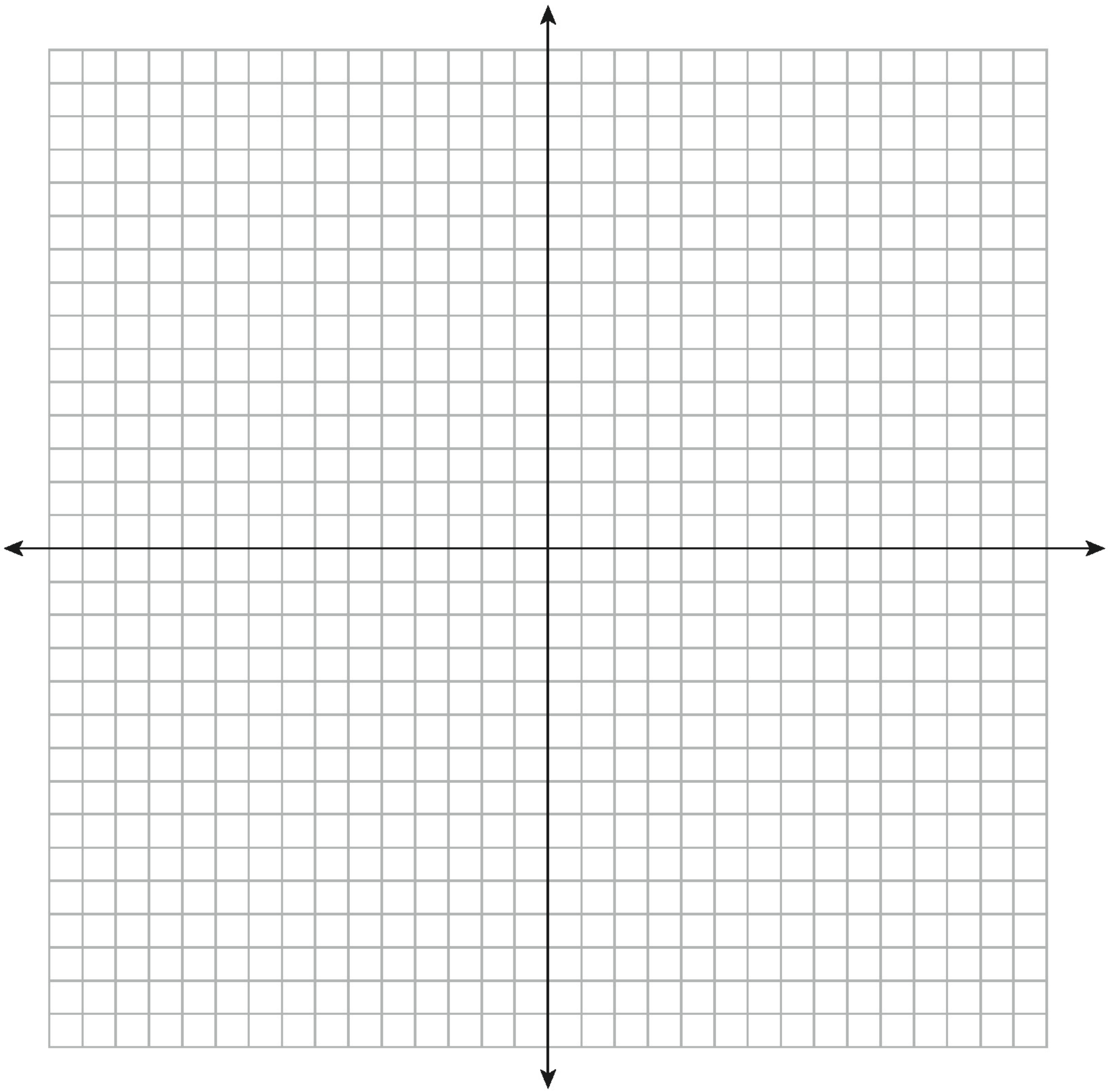
Name: ______________________________

Date: __________ Class: ______________

6 – 8th Grade

Traverse the Terrain – Challenge Terrain

Label the axes and the values on both axes. Then draw the map of your challenge terrain, with all hazards plotted and labeled with the correct coordinates.



Name: ______________________________

Date: ___________ Class: _______________

Traverse the Terrain – Navigate a Rover

In order to guide the vehicle through the challenge terrain, you need to give clear directions using coordinates.

1. Give directions using at least 5 coordinates to get a vehicle from the origin to the goal location your teacher gives your group.
2. Assume the vehicles are moving in a straight line to each coordinate you give them.
3. They can't go around an obstacle unless you tell them to – using coordinates!

Directions for Traversing the Terrain:

Start: (0, 0)

Step 1: ____________

Step 2: ____________

Step 3: ____________

Step 4: ____________

Step 5: ____________

(More steps are optional)

Step 6: ____________

Step 7: ____________

Step 8: ____________

Step 9: ____________

Step 10: ____________

Make sure you test your directions so you know a vehicle can successfully follow them!

Name: ______________________

Date: __________ Class: ____________

Reflecting on the Design Challenge

1. Describe how your design meets the design challenge: ______________________

2. What was the most difficult part of designing your solution? ______________________

3. What was your favorite part of designing your solution? ______________________

4. Explain 2 things that you learned about the coordinate plane during this process:
   a. ______________________
   b. ______________________

Name: ______________________________

Date: __________ Class: _______________

5. If you had another chance to iterate your design, what would you want to do next to improve on your design? ____

____

____

____

Collaboration:

Score your own work with your team and other students throughout the design challenges. Be sure to give reasons to justify your score!

4	I was frequently and actively engaged in sharing, listening and trying ideas from my partners.
3	I was usually engaged in sharing ideas, listening to, and trying ideas from my partners.
2	I was sometimes listening and sharing, and tried to use some ideas from my partners or I took over and did most of the work which didn't allow others to participate.
1	I worked mostly by myself, did not listen or share or use ideas from my partners
My reasons for giving myself this score:	

Name: ______________________________

Date: __________ Class: ______________

ne Terrain – 4-5th Grade

	Below Standard	Approaching Standard	Meeting Standard	Above Sta
Topic **epresent** **problems** **oints in** **ant of the** **ne, and** **dinate** **ts in the** **situation.**	*Areas that individual students may need one-on-one support with*: • Switching the X and Y coordinates (or frequent inconsistencies) of a given coordinate in Quadrant I. • Difficulty consistently identifying the X and Y coordinates in a given set of coordinates (e.g. in point (3,2) 3 is the X coordinate and 2 is the Y coordinate) • When plotting coordinates, placing 2 points for one coordinate; separating the x and y coordinates from a single coordinate. • Mislabeling the origin as a coordinate other than (0,0) • Incorrectly describing the process of finding or plotting coordinates in written instructions.	Part B: • Some errors or inconsistencies in plotting of data from class launches in Quadrant I on the coordinate plane. Part D: • 2-3 errors in identifying all coordinates of 7 obstacles on challenge terrain are. • Written directions for navigating through the challenge terrain do not give a successful path through the obstacles and/or use incorrect coordinates to describe path through the challenge terrain. • Do not fully follow another team's navigation instructions to get through a new challenge terrain.	Part B: • 90-100% of the data from class launches are plotted correctly and with confidence in Quadrant I on the coordinate plane. Part D: • 1 or fewer errors in correctly plotting obstacles on challenge terrain and student can correct their own mistakes in plotting when identified. • Written directions for navigating through the challenge terrain are correct and use correct coordinates to describe path through the challenge terrain. • Correctly follows another team's navigation instructions to get through a new challenge terrain to reach goal without hitting an obstacle.	*Areas where studen exceed:* • Thoroughness a explanation of p find or plot coor Quadrant I. • Ease or speed ir plotting coordin plane. • Written directio navigating throu challenge terrai more points or s required or dem complicated pat the obstacles. *Ideas for next steps* • Introduce Quad the idea of nega coordinates. • Find distances b points that have first or the same coordinate. • Allow students t multiple variatio navigation instru varying levels of

Name: ______________________________

Date: ___________ Class: ________________

ne Terrain – 6-8th Grade

	Below Standard	Approaching Standard	Meeting Standard	Above Sta
Topic **rld and** **l** **graphing** **our** **the** **ane.** d to find een same or the	*Areas that individual students may need one-on-one support with*: • Difficulty consistently moving left/down when using negative coordinate values. • Switching the X and Y coordinates (or frequent inconsistencies) of a given coordinate. • Difficulty consistently identifying the X and Y coordinates in a given set of coordinates (e.g. in point (3,2) 3 is the X coordinate and 2 is the Y coordinate) • When plotting coordinates, placing 2 points for one coordinate; separating the x and y coordinates from a single coordinate. • Mislabeling the origin as a coordinate other than (0,0) • Incorrectly describing the process of finding or plotting coordinates in written instructions.	Part B: • Some errors in plotting of data from class launches in Quadrants I-IV on the coordinate plane. Part D: • 2-3 errors in identifying all coordinates of 7 obstacles on challenge terrain are. • Written directions for navigating through the challenge terrain do not give a successful path through the obstacles and/or use incorrect coordinates to describe path through the challenge terrain. • Do not fully follow another team's navigation instructions to get through a new challenge terrain.	Part B: • All data from class launches are plotted correctly in Quadrants I-IV on the coordinate plane. Part D: • 1 or fewer errors in correctly plotting obstacles on challenge terrain and student can correct their own mistakes in plotting when identified. • Written directions for navigating through the challenge terrain are correct and use correct coordinates to describe path through the challenge terrain. • Correctly follows another team's navigation instructions to get through a new challenge terrain to reach goal without hitting an obstacle.	*Areas where stude exceed:* • Thoroughness explanation of find or plot coo Quadrants I-IV. • Ease or speed i and plotting co on the plane. • Written directio navigating thro challenge terra more points or required or de complicated pa the obstacles. *Ideas for next step* • Find distances points that do r same first or th second coordir • Allow students multiple variati navigation instr varying levels o