Are We There Yet? Mapping It Out with Latitude and Longitude	
Grade Level	Content Standards for 6-8th
Subjects	Physical Science or Earth & Space Science
Duration	Preparation: Minimum (<15 min) Activity: 1.5 hour class time
Setting	Classroom with internet and PowerPoint

Objectives:

In this lesson students will:

1. Be able to explain the concepts of geographic coordinates, latitude and longitude
2. Calculate distances on a map
3. Understand the distortions and differences between types of 3D and 2D maps

Activity Summary

In this lesson, students will be introduced to locating points on Earth using geographic coordinates. They will be introduced to the types of models used to understand the shape and locations on Earth's surface. Students will get to engage in fun activities like creating their own paper globe, finding the geographic locations of famous cities, using a compass and calculating the travel time to Disneyland.

Materials

- PowerPoint Presentation
- Globe
  - Or access to Google Earth
- Activity: Construct a paper globe
  - Paper
  - Heavy cardboard
  - Scissors
  - Tape or glue
- Worksheet: Latitude and Longitude
- Atlas (optional, if available)
- Navigational compass (optional, if available)
- Video: U.S. National Grid

Activity Procedure

Engage - The Earth as a Map [Slides 1-3]

Holding a globe or looking at Google Earth [link from Slide 3], demonstrate to the students that Earth is a sphere, and we can locate standard points on the surface using geographic coordinates measured in degrees. These geographic coordinates are either calculated from the angular distances of the Earth's

center to the surface of the Earth (latitude) or of the angular distances rotating around the poles from a set point (longitude). These measurements are based on the shape of Earth, which is often thought of as a smooth sphere.

At this point, you can break and ask students a couple of simple questions to gauge their knowledge:

1) Which ways are north, south, east and west? (Remind students this is often used for driving directions as well as talking about locations around your city or county).
2) What is the point from which we measure degrees in longitude? (Answer: Prime Meridian)
3) We know that Earth is not exactly a round ball, or sphere, so when we use a sphere to understand the shape of Earth, the sphere is serving as a what? (Answer: a simple model)
4) Great! And how well does a sphere work as a model for Earth, is it actually round and smooth? (Answer: *No!*)

Exploration – Earth's shape [Slide 4]

Our Earth is in fact not round nor is it smooth. So scientists have developed more complex theoretical models of Earth to help account for peaks and valleys of mountains and rivers and the daily rise and fall of ocean tides. Scientists devised a theoretical mathematical surface called an **ellipsoid**. This shape approximates the shape of the actual shape of Earth, which looks like a squashed tennis ball. Also, Earth isn't a perfect, smooth surface, and we can't easily measure from the center of Earth. To understand the approximate height or distance from the center, scientists measure the gravitational force. The resulting shape is a model called a **geoid**. Between these two models, scientists are able to measure Earth in terms of its approximate surface and height locations.

Career discussion:

There are many people who have to understand the concept of the world's shape, the surface and how to measure it, visualize the spatial relationships and how to find various locations on Earth. What type of job would need to know this information?

- Geographic Information System (GIS) specialists
- Geologists
- Pilots
- Meteorologists
- Surveyors
- Various military personnel from satellite controllers to map makers
- Aerospace engineers

Activity: "Punching out the Globe"

Use this paper construction activity to demonstrate the spherical nature of Earth and the challenge of measuring the globe.

Instructions for the globe model

(at Brighthub Education http://www.brighthubeducation.com/help-with-geography/123525-how-to-make-make-a-homemade-globe-for-a-project/ viewed November 2017)

[POTENTIAL BREAKPOINT FOR CLASS SESSION]

Exploration – Latitude/Longitude [Slide 5]

- **Latitude** -- If we picture Earth as a sphere with a line bisecting the center (the Equator) and the two poles as the axis, we would give the Equator a measurement of 0 degrees.
  - This is where we start measuring latitude.
- Latitude is the angular distance between the Equator and the measure of the distance of the angles to points north or south of the Equator.
  - A line of latitude connects all the points with the same angle value in a line around Earth.
  - This can be thought of like stacking donuts in rings one on top of another.
  - Lines of latitude are parallel to the equator and are equally spaced.
  - Think of the Equator as the X bar on an XY graph.
- Much like on a graph, you will find positive 90 degrees of latitude above the equator (north) and negative 90 degrees of latitude below the equator (south).
- **Longitude** is a specific set of locations on the north-south orientation of Earth.
  - For these measurements imaginary lines are drawn that run along the Y axis of Earth, these are perpendicular to the lines of latitude.
  - These lines also touch and connect both of the poles (north and south).
  - The difference between a two dimensional XY graph of latitude is that Earth is round and we must account for the curvature of a circle.
  - There is no clear 0 degrees like the Equator where we can start our measurements, so currently the 0 degree line of longitude runs through Greenwich England.
  - The 0 degree line of longitude is called the Prime Meridian.
  - Think of the planet laid on its end and looking down at the North Pole like a clock, with 360 degrees going east and west (remember north and south is already covered by the latitude).
- The Prime Meridian would be at 6 o'clock and be 0 degrees (pointing down).

Question and Answer Opportunity:

- Ask students what the degrees would be around the outside the rest of the clock to complete the circle, how many degrees would there be? (Answer: 360).

- What would be the position of “Noon” if the Prime Meridian is at 6 o’clock? (Answer: would be 180 degrees).
- Now say that the clock is split with the left side west and the right side east; what would the time be at 90°W? (Answer: 9 o’clock)
- And what time would 90°E would be? (Answer: 3 o’clock).

Exploration - Map Distortions [Slide 6]

- Show the students the different types of maps showing latitude and longitude
- These different types of maps are called “Projections”
- Ask “which map is right?”
  - Answer: all the maps are right and wrong, choosing to preserve one feature of Earth’s surface such as “shape” of objects, vs. “size” of objects, vs. “relative location”
- What is causing the distortion?
  - Answer: trying to show a 3D object in two dimensions always causes distortions of some kind. Remember that India is on the opposite side of the Earth but they appear to be side by side in each of these maps!
- Which is most accurate for shape?
  - Answer: Mercator is most correct for the shape of the land, but completely wrong in relative location or size.
- Which is most accurate for size?
  - Answer: Robinson is most accurate for size, but is incorrect for relative location and shape.
- Why do we use Plate Carree then?
  - Answer: It shows the relative north-south and east-west positions most accurately, even though the shape and size are completely wrong.
- Bonus: Do these errors get better or worse as we zoom in and make 2D maps of smaller parts of the 3D Earth?
  - Answer: the problems actually go away as we zoom in and flatten maps that are smaller portions of earth, because they are closer to being actually flat from a bird's’ eye view. In these cases we use the Mercator projection to preserve shape.

Exploration: Geographic Phenomenon

Discuss some of the following topics:

- Time Zones
  - What do we do to normalize time in certain areas, what do we use? (Answer: time zones)
  - Did time zones always exist? What drove the need for time zones? (Answer: coordinating train schedules).
  - Why would that matter? Why can’t we just say trains will arrive at noon or 1pm? (Answer, because noon and 1PM are different times across even small distances, so standard times were needed to coordinate travel across long distances).

- Hemispheres
  - What do we call the top half of Earth? (Answer: Northern Hemisphere)
  - And the southern half? (Answer: Southern Hemisphere)
  - What's some of the differences between them?
    - What stars are visible
    - Number of people that live there
    - The seasons are reversed
    - The water spins the other way down the toilette
  - What divides these Hemispheres? (Answer: the Equator)
  - Are there other major Hemispheres than North and South? (Answer: East and West)
  - What divides the Eastern and Western Hemispheres? (Answer: Prime Meridian)

- Latitude and Climate
  - Ask about how the weather changes in general with latitude - is it coldest in the north or the south? Where is it hottest? (Answer: it's cold in the north AND the south, and hot at the Equator).
  - What do we call the most northern areas? (Answer: Arctic)
  - What do we call the most southern areas? (Answer: Antarctic)
  - If we go far enough north in the northern winter what happens to the sun for those that live there during the day? Do they see it? (Answer: it never shows up, it stays dark all day)
  - What do we call the line at which it stays dark all day in the northern winter? (Answer the Arctic Circle)
  - What do we call that same line, only in the south? (Answer: Antarctic Circle)
  - At what locations do we see equal amounts of day and night throughout the year? (Answer: within the Tropics).
  - What is the northern latitudinal boundary for this area called? (Answer: Tropic of Cancer)
  - What is the southern latitudinal boundary for this area called? (Answer: Tropic of Capricorn)

Elaborate on how to use latitude and longitude. Begin by asking students how they would very precisely find locations on a map especially if a location fell between the major lines of latitude and longitude. How would they express that point?

- Ideas on how to express the distance between two geographic coordinates:
  - Decimal degrees - divide the degrees and use a decimal number
  - Add a distance - include both the geographic degrees plus some distance from that degree location (e.g. 20 miles above 40 degrees North)
  - Time - include the time differences between the major degree lines and the location (e.g. 5 hours West of 40 degrees West).

- Introduce them to the subdivision of longitude and latitude into minutes and seconds. There are 60 minutes per degree, written as ('), and there are 60 seconds per minute ("); again, think of the clock.

  1° of latitude = ~ 69 miles

  1 ’of latitude = ~1.15 miles

  1" of latitude= ~ 100 ft.

- Ask whether the numbers of latitude would ascend or descend towards the poles?
  Answer: They would descend towards the poles to reach 0 degrees, with a negative value below the equator and a positive value above the equator. This means that the minutes and seconds of longitude also vary as they decrease in size towards the poles.

Exploration - Explaining the Compass

- Hold up a navigational compass for the students. Explain what a compass is for and how it might be used, referencing examples such as finding your way in the woods when camping or hiking or sailing on the ocean. Ask the students if they have ever used a compass and invite them to tell their own stories about how they did so.
- Review the fact that a circle has 360 degrees and point out that north is at 0 degrees and east at 90 degrees, south at 180 degrees and west at 270 degrees. Breaking down the directions into degrees is useful for those times when you want to travel in a direction other than simply south or southeast
- The colored part of the needle should always be lined up with north before you can take a reading (usually it’s red or green). Demonstrate taking a reading by first asking the students to identify an object in the room (such as a chalkboard). Holding the compass out in front of you, turn it so that the red part of the needle lines up with the “N” and then estimate the direction you would need to take to reach the chalkboard or other object.

Demonstrate: Application of Latitude, Longitude and Cardinal Directions [Slide 8]
This may extend into another class session or can be completed as a homework assignment

1) **Have students complete Latitude/Longitude exercise**
   a) Handout and Review Worksheet on Latitude and Longitude

2) **Planning a trip to Disneyland**

   a) Use Google Earth to find the latitude and longitude of your location.
   b) Divide students into teams of 4 and have them plan a driving trip to Disney World:
      i) Students should plan stops along the way, calculate the total driving time and distance

ii) Students should write down the latitude and longitude of each planned stop as well as Disney World

c) Share with students the FCC website for conversions at: https://www.fcc.gov/media/radio/dms-decimal

d) You may wish to find the specific decimal degrees of your school on Google Maps ahead of time and then have the students give you back the specific degrees in minutes and seconds.

Optional Discussion - US National Grid [Slide 9]

- In some states in North America, emergency responders use a grid system to help identify locations for purposes of search and rescue. This is a map with lines (the grid) placed on the map. This grid provides an alphanumeric point reference system that can lead someone to discrete locations using 2 letters (which reference the region) and 8 digits. It is an unambiguous way to describe locations when the end-user is operating either in an area away from established road networks or in an area impacted by a natural disaster where road signs have been destroyed.
- The U.S. National Grid (USNG)
    - Is easy to learn
    - Enables user-friendly position referencing on appropriately gridded paper and digital maps, with GPS receivers and WWW map portals
    - Is easy to say and repeat over radio and phone using a universal standard
    - Is used by FEMA in emergency situations
    - Can be used when internet access is not available
- Let's learn a little more about this navigation technique through a video
    - After watching video, teacher should note that USNG is a standard geographic reference systems across all preparedness, mitigation, response and recovery activities as well as land-based operations undertaken for a wide range of search and rescue efforts.
    - This includes activities such as wildfires, flooding, mudslides, tornados, hurricanes, plane crashes, marking trails or emergency shelters to know a few
    - Anyone can use this method even if they don't have a smartphone

Key Terms for Students

Latitude: A specific location found on the angular distance between the Equator and the measure of the distance the angle to points north or south of the Equator.

Longitude: A specific location on the east-west orientation of the Earth.

Prime Meridian: Earth's central line of longitude defined as 0 degrees.

Equator: On a sphere it is the intersection of a plane that is perpendicular to the sphere's axis of rotation, located between the two poles of the sphere. On Earth, this is an imaginary line dividing the planet in half equidistant from each pole and dividing Earth into Northern and Southern Hemispheres.

Universal Time: This is a 24-hour time standard that is kept using highly precise atomic clocks combined with Earth's rotation

Magnetic North: The direction in which the north end of compass needle or other freely suspended magnet will point in response to Earth's magnetic field. It differs from the true north over time and from place to place because Earth's magnetic poles are not fixed in relation to its axis.

True North: North according to Earth's axis

Ellipsoid: A three-dimensional figure resembling a flattened sphere.

Geoid: The hypothetical shape of the earth, coinciding with mean sea level and its imagined extension under (or over) land areas.

Mercator Projection: A type of map that is a cylindrical representation of the earth. It is widely used for navigation charts

Robinson Projection: A world map which shows the entire world at once.

Climate: The weather conditions prevailing in an area in general or over a long period.

Degree: A unit of measurement of angles, 1/ 360 of the circumference of a circle.

Angle: The space between two intersecting lines or surfaces at of close to the point where they meet. Usually measured in degrees.

U.S. National Grid: A presentation standard that provides a nationally consistent language of location using a grid reference system that is seamless across jurisdictional boundaries. It does not replace data storage formats (such as GIS or GPS).

Background for Educator

This is the introductory lesson from a 12-lesson curriculum introducing STEM topics through the lens of GPS and many uses in our lives. The lessons include discussion of various STEM careers related to GPS, and the activities provide practical applications that may be used in various career fields. Module 1 of the STEM curriculum includes this introduction to mapping plus two more lessons on radio waves and the Global Positioning System (GPS).

Additional Background

- Again, like the values on an XY graph the values of longitude going east of the Prime Meridian are positive and the values going west of the Prime Meridian are negative.
- Longitude is also used to determine time zones. Local times (LT) are calculated based on the position of the sun relative to where you are right now.
- However, Universal Time (UT), which is used to calculate astronomical events, and time around the world, is calculated using longitudinal degrees.
- Each day the Earth rotates by 360°.

- So, if you divide 360°/24 hours = 15° degrees.
- When it's noon at your location then 15° to the east it will be 1 pm and 15° to the west will be 11 am.

Next Generation Science Standards

MS-ESS1-B Earth and the Solar System;

- With connections to scientific assumptions on order, consistency and patterns occurring in natural systems.

MS-ESS1-3 Analyze and Interpret data to determine scale properties of objects in the solar system