**TITLE: Where’s My Phone?**

***Subtitle: Using GPS to Learn About Location on the Earth’s Surface***

**Overview:**

Students learn how to use latitude and longitude to describe location on the Earth’s surface. Students also learn how Global Positioning Systems (GPS) function and how we can use everyday technology (for example, smart phones) to find latitude and longitude. Two concepts are introduced and/or reviewed: 1) Properties of electromagnetic waves (the speed of light and the relationship between distance, velocity and time), and 2) Geometric concept of triangulation.

The students map the point locations of some object of interest (for example trees, garbage cans, restrooms, benches, etc.) and then view the results of their mapping as displayed in a web page and in Google Earth®. They also learn how to place their maps into a word processing (Microsoft Word®) document.

**Concepts:** Latitude and Longitude, Equator and Prime Meridian, GPS (Global Positioning System), GPS History, GPS and Triangulation, Speed of Light, Distance = Speed x Time

**Skills:** Using Latitude and Longitude to Locate Features on the Earth’s Surface, Creating Waypoints and Tracks on GPS Devices, and Making a Simple Map with GPS Devices and Computers.

**Module Type:** Field project (mostly recipe style)

**Duration:** one 30 min preparation lecture, and one 2-hr class session

**Key materials:**

* Smart Phones (from students: iPhone or Android) or iPads (from the school)
	+ one device for groups of three to four students
* Field data sheet/clipboards (one per group)
* Computers with a web browser (IE®, Google Chrome®, Firefox®, etc.), Google Earth® and Microsoft Word® installed - one for each group

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**Science Education Standards:**

**National:** A. Science as Inquiry, E. Science and Technology, G. History and Nature of Science

**California:** Physics: 4e, Investigation and Experimentation: 1a, 1e, 1h, 1k

**Next Generation Science Standards:** HS-PS4: Waves and their applications in technology; MS-PS3: Energy (Crosscutting concepts: scale, proportion, and quantity)

NGSS science and engineering practices; Practices 3 (investigating), 5 (mathematical thinking) and 8 (obtaining, evaluating and communicating information).

**National Standards for History:** Thinking standards: 2 (maps as data) and 3 (role of chance in history)**,** United States History Standards (Era 10, 1968 to present): 1, 2.World History Standards (Era 9, the 20th century since 1945): 1.

**Common Core State Standards for Mathematics in California Public Schools:** Geometry 12.0 (grades 9-12): constructions with a straight edge and compass, Algebra 9.0 (grade 6): expressions and equations

**Field tested with:** 9th grade Integrated Science 1 students, Watsonville High School, Watsonville, CA.

**Starting Point for Inquiry:**

What to map? Why? How can the map be used? What purpose might the map serve in our society?

**Background for Teachers**

“Location, Location, Location”.We have all heard this age-old adage that stresses the importance of location for business success. This common sense knowledge can be expanded to stress the importance of location for the success of any project, be it a political advertising campaign, recycling, or habitat restoration, just to name a few. To describe location on the Earth’s surface we use a coordinate system that uses measures of **latitude** and **longitude** that are much like X and Y Cartesian coordinates on a graph. Instead of describing location in Cartesian space on flat paper in two dimensions, latitude and longitude describe location on a surface similar to a sphere using **angular coordinates** in three dimensions. Just like a graph which has an origin point of (0,0) the coordinate system of latitude and longitude also have an origin of 0° (zero degrees) latitude and 0° longitude.

The **Equator** is the line of 0° latitude that divides the earth into the **northern hemisphere** and **southern hemisphere**. The equator is exactly half way between the North Pole and the South Pole. It follows that latitude measures the distance north or south from the equator. The **North Pole** is 90° latitude and the **South Pole** is -90° latitude. If we look at a globe with the North Pole on top, the lines of latitude will appear horizontal. An easy way to remember this is that Latitude sounds like the word “flat.” Another way to remember this is that latitude sounds like “ladder”, and ladders are used for going up and down (like latitude is used for measuring north and south).

The **Prime Meridian** is the line of 0° Longitude that divides the Earth into the **eastern hemisphere** and **western hemisphere**. The placement of the prime meridian at **Greenwich** in the United Kingdom is arbitrary and was chosen at a time when the British Empire was the most powerful empire on the earth. It follows that longitude measures the distance east or west of the prime meridian, or east or west of London (Greenwich), England. There are 360° of longitude (just like a circle) as it circumscribes the earth from London to London, but we divide longitude into two parts: 180° west to 180° east. The 180° midpoint of longitude lies just east of New Zealand. If we look at a globe with the North Pole on top, the lines of longitude appear vertical. An easy way to remember this is that it looks like the slices of an orange which sounds a little bit like longitude (with the ‘g’). Another way to remember this is that longitude is long (the lines appear longer than latitude with the exception of the equator).

During the last several decades, as satellite technology advanced and (perhaps more importantly) public access to satellite technology became available, **Global Positioning Systems (GPS)** have become common in many devices in our lives (two examples are the GPS in car navigation systems and the GPS in cell phones). Understanding how this technology works, how it can ‘find’ or ‘measure’ latitude and longitude, and how to use it is now an important aspect of belonging to our present day society. At a very basic level, GPS uses radio signals sent by a network of **satellites** and interpreted by **receivers** that use the speed of electromagnetic waves (the radio signals) and the position of the satellites to **triangulate** location on the Earth’s surface. Even though this technology may seem “magic,” it was built by people and needs people to function correctly.

It is important to understand that GPS technology is recent and has only existed since about 1960. Indeed, in 1960 it barely worked (the receiver needed a long period of time to “fix” its position, and even then the results were only accurate to one-hundred meters). Originally, **GPS** was **invented** by the **US military** as a part of the nuclear defense system during the **Cold War**. The 100 meter accuracy was sufficient to track submarines and guide nuclear missiles. The GPS satellite system first became **operational** in **1978** and the **public** (i.e. the private sector) was given access in **1983** after the **Korean Air Flight 007** incident. In this incident, a civilian jet liner had strayed from its flight path into Russian airspace and was shot down by the Russian air force. The president of the United States, Ronald Reagan at that time, quickly created legislation to give the public access to the signals from the network of GPS satellites.

The United States currently has a system of **32 satellites in orbit** dedicated to GPS and has made the highly accurate signals accessible to the public (**everyone**) since **2000**. In 2013, a cell phone (or any other GPS receiver) needs about **three minutes** to fix a position that is accurate to about **five meters**. When using GPS for any application it is always important to give the receiver a few minutes of “stationary time” in order to get better, more accurate results (when you are marking a waypoint, wait for a few minutes while standing still before marking the position). Since about 1995 the GPS technology has advanced rapidly, mostly for the receivers. Much like computers, GPS technology becomes smaller, faster, and more accurate through time.

GPS uses **triangulation** from several satellites to find location (NOTE: the correct term is trilateration, but *everyone* uses the term triangulation). For GPS we know the location of the satellites (the satellites communicate with known markers on the surface of the Earth) and we use **distance** from at least five satellites to determine position through triangulation. In two dimensions we need at least three known points (see the lecture PowerPoint), and for GPS we need at least five satellites. Across the surface of the Earth you can always “see” around nine satellites (sometimes less in places where the signal is blocked, for example, steep valleys or inside a building).

The calculations for distance use the **Speed of Light**: the time for the radio signal to travel from the satellite to the receiver is measured and then distance can be calculated with the equation **distance = speed x time**. Radio signals are electromagnetic waves and travel at the speed of light. Note that the speed of light is very fast: **3 X 108 meters/second or 186,000 miles/second**. The calculation with the speed of light presents a good opportunity to review several teaching standards: the speed of light, simple relationships between velocity, distance and time, and scientific notation for expressing large numbers. We know that the **satellites** are at an **altitude** of approximately 20.2 million meters (20.2 X 106 meters) and we also know the speed of light. With a simple calculation we find that it takes about 7 one-hundredths (7 X 10-2 seconds) of a second for light to travel from the satellite to our receiver.

20.2 X 106 meters = 3 X 108 meters/second X time

|  |  |  |
| --- | --- | --- |
|  20.2 X 106 meters 3 X 108 meters/second | ~ | 7 X 10-2 seconds |

**Curriculum Notes (how this fits into the larger curriculum picture)**

Previous teaching concepts (suggested):

Triangulation of earthquake epicenters (see <http://nees.org/resources/4026/>)

Distance = velocity \* time (review)

Teaching objectives for this module (from above)

**Concepts:** latitude, longitude, equator, prime meridian, GPS (Global Positioning System), GPS history, GPS and triangulation, speed of light, distance = speed x time

**Skills:** how to use latitude and longitude to locate features on the earth’s surface, how to create waypoints and tracks on GPS devices, and how to make a simple map with GPS devices and computers.

Next teaching concepts (suggested):

Using latitude and Longitude to locate tectonic plate boundaries, use latitude and longitude to locate of other geographical features on the surface of the Earth

Major regions in world: tropical, arctic, temperate

Continents: basic shapes, names, and locations

**Project Description**

**Materials:**

* Smart Phones (from students: iPhone or Android) or iPads (from the school)
	+ one device for groups of three to four students
* Field note books/clipboards (one per group)
* Computers with a web browser (IE®, Google Chrome®, Firefox®, etc.), Google Earth® and Microsoft Word® installed - one for each group

**Preparation:**

There are several things to prepare before teaching this module

1. (10 min) Print out the “GPSNotes.doc” and the GPSActivity.doc.” Make two sided copies of both documents (one for each student).
2. (5 min) If you are using iPads from the school, make sure all of them have the app Trimble® “My Topo Maps” installed (it is free).

NOTE: the app for the smart phones IS DIFFERENT!! If you are using smart phones you and the students will use the app Trimble® “Trimble Outdoors Navigator” (the free version). The smart phone app is BETTER.

1. (5 min) Go to the Trimble® Outdoors website, <http://www.trimbleoutdoors.com/>, and create a class username and login (we recommend that all students use the same login). Enter the login and password on slide 29 of the “GPSLecture.pptx.”
2. (20 min) Make sure you are familiar with the application on the smart phones and on the iPad (depending what you plan to use). Go through the procedure outlined in the document “GPSActivity.docx” once (it is really quite simple). Use the “GPSHelp.pptx” if you need extra instructions.
3. Make sure the class/lab computers have Google Earth® installed.
4. Set up the charging station before class (talk to Will Federman).

**Timeline: (30 min preparation lecture and 2 hour activity)**

30 min preparation lecture:

1. (30 min) Lecture – latitude and longitude: location on the earth’s surface

Two hour class period:

1. (5 min) As the students walk in get them to download the app on their smart phone (if they have one) and leave the phone at the charging station.
2. (30 min) Lecture – GPS history, speed of light, satellites, triangulation – how GPS works
3. (5 min) Break into groups and distribute equipment (or divide students into groups with smart phones)
4. (15 min) hands on GPS training, get phones ready (I do, we do, you do) . . .
5. (25 min) map locations (outside)
6. (10 min) re-group/upload data
7. (20 min) edit maps in Google Earth® and Microsoft Word®
8. (10 min) check-in/review/assign homework

**Possible pitfalls:**

* GPS Technology is easy to use – students might think this will be easy
* Fear of technology – hard to trust what is going on (opposite of above)
* Batteries run out on smart phones (set up charging station during lecture)
* Memory runs out on smart phones
* Time/supervision (students use smart phones for other purposes)
* Installations of app takes time (perhaps assign as homework the week before or do it at the beginning of class?)
* Make sure everyone uses the same user name and login.
* You MUST ‘start the trip’ to get waypoints and phones. DO NOT overlook this step
* Weather might be an issue (outdoor activity)
* Ceilings and overhead structures interfere with the GPS signal
* Smart phone and privacy issues (not everyone wants to be tracked)
* If you are using iPads, the app does not intuitively record photographs; it is an extra step and does not give the best results.

**Procedure:**

30 min preparation lecture:

1. (30 min) Lecture – latitude and longitude: location on the earth’s surface
	1. Lecture through slide 8 in the powerpoint “GPSLecture.pptx”
	2. The students should complete the first page of the “GPSNotes.docx” as the lecture proceeds
	3. Assign a simple homework exercise in which the students locate features (cities, volcanoes, etc.) on the earth’s surface using latitude and longitude (Will has some good resources)

Two hour class period:

1. As the students walk in to the classroom, get them to download the app on their smart phone (if they have one) and leave the phone at the charging station.
	1. Remember the smart phone app is Trimble® “Outdoor Navigator”
	2. Have the students log into the wireless network with their smart phones (less expensive than using minutes)
	3. See Will Federman about the charging station
2. (30 min) Lecture – how GPS works, speed of light, satellites, triangulation
	1. Lecture from slide 9 through slide 26 in the powerpoint “GPSLecture.pptx”
	2. The students should complete the second page of the “GPSNotes.docx.” NOTE: probably help them with the calculations (I do, we do, you do).
3. (5 min) Break into groups and distribute equipment (or divide students into groups with smart phones)
	1. Use slide 28 and have the groups decide what they will map
	2. Quickly check that each group understands they are mapping *waypoints.*
4. (15 min) Hands on GPS training, get phones ready (I do, we do, you do) . . .
	1. Use the slide 29: make sure everyone is logged in to the correct account
	2. Use slides 30 through 36 to show the students the three (3) key steps to marking waypoints and recording a trip.
		1. Start Trip
		2. Mark a Waypoint (REMEMBER: wait two or three minutes for a good ‘fix’ on the location)
		3. End Trip
	3. NOTE: the “End Trip” step automatically uploads the data to the Trimble Outdoors website (<http://www.trimbleoutdoors.com/>)
	4. Make sure that all groups created a trip, marked a waypoint, and ended the trip all within the classroom.
	5. Make sure all groups have one person designated as a notes taker. The notes taker should design their own table with columns for:
		1. Waypoint Name
		2. Latitude
		3. Longitude
		4. Notes/description (what the feature is)
5. (25 min) Map locations (outside)
	1. The students should “start” another trip (or continue the “Trip” from 5)
	2. Give them about 25 minutes to go outside and mark their waypoints
	3. Remind them to take notes as they go (good field habit)
6. (10 min) Re-group/upload data
	1. Make sure all groups “end” their trip when they return to the classroom, it will “synchronize” automatically and upload their data.
7. (25 min) Edit maps in Google Earth® and Microsoft Word®
	1. (screens off) Walk the students through the procedure to login to the Trimble® Outdoors website (<http://www.trimbleoutdoors.com/>), download their trip file (KML), get a simple map from the website itself, and paste the map image into Microsoft Word® (see the instructions on the back of the GPS Mapping Activity Handout (GPSActivity.docx).
		1. In Google Earth® Show the students the option to view the latitude-longitude grid: menu: View->Grid (or CTRL-L).
	2. (screens on) The students create a Microsoft Word® file with two maps, one from the Trimble website and the second from Google Earth®.
8. (5 min) Check-in/review/assign homework
	1. Homework: write a paragraph about why the group chose to locate the features they mapped (see the Homework sheet in “GPSActivity.docx”).

**Assessment Methods:**

* The group correctly marks at least six (6) waypoints, transfers the file correctly to the computer and creates a simple Microsoft Word document with the two maps.
* The group turns in a set of field notes with waypoint names, latitudes, and longitudes recorded in an orderly manner.
* Each student turns in their completed ‘GPSNotes’ from the lecture.
* Each student turns in their activity worksheet.
* Each student completes the homework assignment.

**Science Education Standards Addressed:**

This module focuses on simple concepts in Physics and Math and how they are applied in Global Positioning System (GPS) technology. It addresses:

**National Science Education Standards (NSES):**

(<http://www.nap.edu/catalog/4962.html>)

 A. Science as Inquiry (p.175-176)

 E. Science and Technology (p.192-193)

1. History and Nature of Science (p. 200-204)

**Science Content Standards for California Public Schools (SCSCPS):**

(<http://www.cde.ca.gov/be/st/ss/documents/sciencestnd.pdf>)

Physics**,** 4. Waves have characteristic properties that do not depend on the type of wave. As a basis for understanding this concept:

 **e.** *Students know* radio waves, light, and X-rays are different wavelength bands in the spectrum of electromagnetic waves whose speed in a vacuum is approximately 3 x 108 m/s (186,000 miles/second).

Investigation and Experimentation, 1. Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing content in the other four strands, students should develop their own questions and perform investigations. Students will:

**a**. Select and use appropriate tools and technology (such as computer-linked probes, spreadsheets, and graphing calculators) to perform tests, collect data, analyze relationships, and display data.

**e.** Solve scientific problems by using quadratic equations and simple trigonometric, exponential, and logarithmic functions.

**h.** Read and interpret topographic and geologic maps.

**k.** Recognize the cumulative nature of scientific evidence.

**Next Generation Science Standards (NGSS)**

Appendix F – Science and Engineering Practices in the NGSS:

(<http://www.nextgenscience.org/sites/ngss/files/Appendix%20F%20%20Science%20and%20Engineering%20Practices%20in%20the%20NGSS%20.pdf>)

Practice 3: Planning and carrying out investigations

Practice 5: Using mathematical and computational thinking

Practice 8: Obtaining, evaluating and communicating information

**DCI Arrangements of the Next Generation Science Standards**

(<http://63960de18916c597c345-8e3bed018cb857642bed25a591e65353.r63.cf1.rackcdn.com/Combined%20DCIs%205.15.13.pdf>)

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| --- |
| HS-PS4 Waves and Their Applications in Technologies for Information Transfer (p 80)HS-PS4-5.Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.\* |

*Disciplinary Core Ideas*

PS4.C: Information Technologies and Instrumentation

Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research. They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them. (HS-PS4-5)

MS-PS3 Energy: (p 56)

*Crosscutting Concepts*

Scale, Proportion, and Quantity: Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

**National Standards for History**

**Historical Thinking Standards** (<http://www.nchs.ucla.edu/Standards/>)

Standard 2: **The student comprehends a variety of historical sources (draw upon data in historical maps)**

Standard 3**: The student engages in historical analysis and interpretation (Analyze cause-and-effect relationships**bearing in mind**multiple causation**including (a)**the importance of the individual**in history; (b)**the influence of ideas,** human interests, and beliefs; and (c) the role of chance, the accidental and the irrational).

**United States History Content Standards (Era 10, 1968 to present)** (<http://www.nchs.ucla.edu/Standards/us-history-content-standards/us-era-10>)

1. Recent developments in foreign and domestic politics
2. The student understands major foreign policy initiatives.
	* + 1. Economic, Social, and cultural developments in contemporary united states
				1. The student understands economic patterns since 1968.

**World History Content Standards (Era 9, the 20th century since 1945)**

(<http://www.nchs.ucla.edu/Standards/world-history-standards/world-era-9>)

1. Major global trends since World War II
2. The student understands major global trends since World War II.

**Common Core State Standards for Mathematics in California Public Schools**

(<http://www.cde.ca.gov/ci/ma/cf/documents/ccssmathapril2013.doc>)

Geometry (grades 9-12): (p 74-5)

1. Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.).

Expressions and Equations (grade 6): (p 43)

9. Use variables to represent two quantities in a real-world problem that change in relationship to one another; write an equation to express one quantity, thought of as the dependent variable, in terms of the other quantity, thought of as the independent variable. Analyze the relationship between the dependent and independent variables using graphs and tables, and relate these to the equation. *For example, in a* *problem involving motion at constant speed, list and graph ordered pairs* *of distances and times, and write the equation d = 65t to represent the* *relationship between distance and time.*

**Appendices**

**Glossary**

Latitude: An angular measure indicating distance north or south of the equator on the surface of the earth

Longitude: An angular measure indicating distance east or west of the prime meridian on the surface of the earth

Cartesian Coordinates: X and Y coordinates measured from a (0,0) point of origin that describe location on a flat plane.

Angular Coordinates: horizontal and vertical angles measured from a (0,0) point of origin that describe location on a sphere.

Equator: The 0° (zero degrees) line of latitude.

Northern/Southern Hemisphere: The halves of the earth north or south of the equator.

North/South Pole: The points on the surface of the earth furthest from the equator; either 90° north or -90° south. The poles are also the points through which the axis of the earth passes.

Prime Meridian: The 0° (zero degrees) line of longitude.

Eastern/Western Hemisphere: The halves of the earth east or west of the prime meridian.

Greenwich: The town in England through which the prime meridian passes (arbitrary)

Global Positioning Systems (GPS): A system that uses GPS satellites (in orbit around the earth) and GPS receivers to determine latitude and longitude (position) on the earth’s surface.

GPS Satellite: Satellites specifically designed to send GPS signals.

GPS Receiver: A receiver specifically designed to receive GPS signals and calculate location.

**Lectures**

GPSLecture.pptx

(this file includes both lectures: Latitude/Longitude and GPS)

**Graphics**

All images are sourced or referenced in the GPSLecture.pptx file. If there is no source or reference for an image then it was created by the author Timothy B. Norris. All of the images in the GPSNotes.docx are drawn from the lecture Powerpoint.

**Labs (or Activities) / Worksheets / Assessment Materials**

GPSNotes.docx

(this includes the scaffolding for both lectures)

GPSActivity.docx

(this includes the “lab” activity, the instructions, and the homework)

GPSHelp.docx

(this includes extra instructions for the smart phone apps, Google Earth and Word)