ABSTRACT

Many students have heard of Global Positioning Systems (GPS) as a navigation tool, but few know exactly what this complicated technology is, or how widespread are its applications are. For instance, many luxury cars now use the same GPS technology as tractors. In addition to navigators, military personnel and farmers use GPS. This lesson teaches students about how GPS technology works and why it is useful. *Mapping by Satellite* develops skills used in scientific research, medicine, mathematics, and even business. In this lesson, students make connections between two-dimensional graphs and three-dimensional maps, learn to generate and analyze 3-D graphs, and simulate the real world applications of GPS technology.

LEARNING OBJECTIVES

Students will

- generate and analyze 2-D and 3-D maps and graphs;
- learn how GPS technology works;
- learn the applications of GPS as a navigation and agricultural aid; and
- appreciate how researchers use analytical tools to create images that portray information too complex for traditional charts and tables.

TIES TO CURRICULUM

Most science and math curricula barely touch upon the practical application of 3-D mapping techniques. *Mapping by Satellite* weaves together the concepts of 2-D and 3-D mapping to apply both chemistry and mathematics to visual images. This lesson conforms to curriculum and instruction frameworks of the National Council of Teachers of Mathematics' *Mission Mathematics* and the National Research Council's *National Science Education Standards*. These two sets of standards challenge students to engage in real world applications, reason and problem- solve, acquire and evaluate information, and make connections between disciplines. Students do all of these things in *Mapping by Satellite*.

NUMBER OF LAPTOPS AND GROUP SIZE

Each group of five students needs one laptop computer.

TIME REQUIREMENT

This lesson takes approximately eight hours.

Task	Time	Location
Introduction		
Background	2 hours	Classroom/library/home
Mapping and GPS	3 hours	Classroom
Field activity	3 hours	Field

LESSON DESCRIPTION

MATERIALS

- Laptops with 8 Mg RAM and 20 MB Hard drive with internal CD-ROM drive
- 3-D graphing software (e.g., Wolfram's Mathematica)
- Magellan GPS 315 Receiver
- GPS Software (compatible with Magellan GPS 315 Receiver)
- Soil analysis kits (follow the soil analysis procedures provided in the soil kit)
- Soil and fertilizer supplements
- Microplates

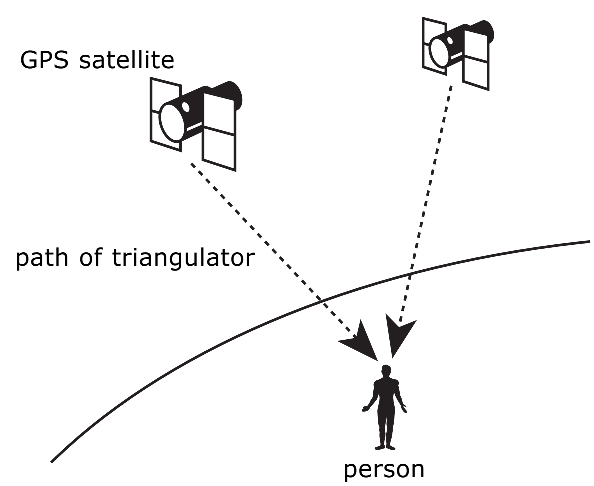
Introduction

Background

Ask students if they have had experience with global positioning or knew anyone involved with Global Positioning Systems (GPS) in his or her job. Review what GPS is and how the technology works.

GPS determines exact positions by "triangulation" through satellites. To "triangulate," a GPS receiver measures distance using the travel time of radio signals, and the height of satellites in space (see Figure 1). The receiver must correct for any delays the signal experiences as it travels through the atmosphere.

Figure 1: How GPS works



Discuss the applications of GPS—for example, GPS has made a huge impact on agriculture in the last decade. Farmers traditionally sampled one or two small sections of their fields and tested soil type and chemical content to determine which fertilizers and other chemicals were needed to improve crop productivity. Farmers are often in the difficult position of choosing between a need to improve crop yield, and a need to limit the use of fertilizer and chemical additives due to high costs and the impact of chemicals on the environment. With GPS technology, a farmer can collect and analyze samples while controlling the machinery to vary fertilizer application. The farm of the future, equipped with GPS, will have several pieces of equipment to harvest grain and apply chemicals, with computers monitoring the location of each machine.

As a homework assignment, students can research applications of GPS technology as a tool for mapping, navigation, or military practice.

Mapping and GPS

Explain to the students that they will use GPS technology to create a map of a local site, complete with chemical information. Review latitude and longitude, and using coordinates to make two-dimensional graphs. You may wish to do problems converting latitude and longitude into x, y coordinates and back again. Then do triangulation problems to demonstrate how to compute location using a satellite and GPS receiver.

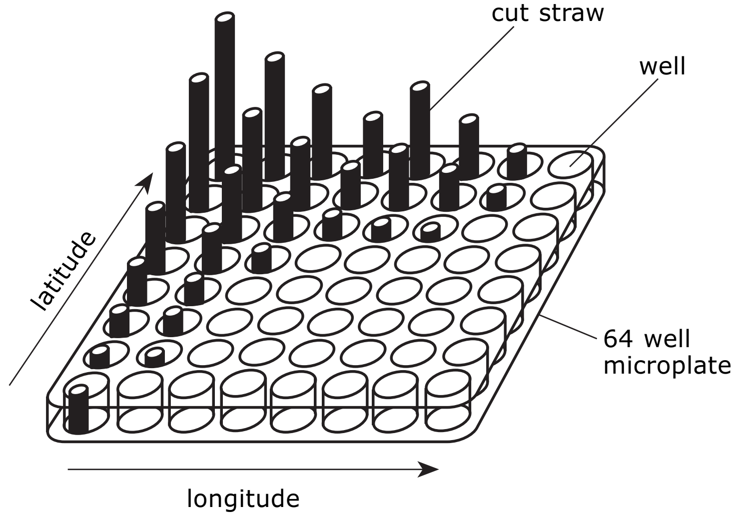
Give students field positions and chemical data, such as nitrogen content or pH. From that data, students should generate a two-dimensional graph representing position and soil content, color-coding the range of nitrogen content or pH. Discuss the limitations of 2-D maps and explain that 3-D mapping is best used to convey both position—latitude and longitude—and information about the field, such as chemical content or crop yield. The following exercise gives students an opportunity to conceptualize a 3-D map or graph.

Using straws and a small microplate (a shallow plastic dish with approximately 96 wells), students determine a scale length for their map. They then cut the straws and arrange them vertically in the microplate. The horizontal position of the wells represent latitude, the vertical position represents longitude, and the height of the straw is the value of the chemical data (see Figure 2).

SUGGESTIONS

- You can find soil analysis kits, soil, and fertilizer supplements at garden stores or through chemical supply catalogs. Microplates can also be ordered from chemical supply catalogs.
- If you live in an area where there is a lot of farming, contact local extension agencies, soil and water conservation agencies, or agricultural chemical suppliers for additional information and local soil and chemical analysis maps. Students can compare their data to those of agency maps of each field site.
- If your school is not in an agricultural area, conduct soil analysis and mapping in a land lab near school.
- As an extension, determine the error in global positioning: each group maps the same point at school, and compares results. Assign a short project investigating the potential causes of measurement error.

Figure 2: The microplate map



Divide the class into groups of five students. Demonstrate position location using a GPS receiver and laptop computer, and have groups practice. For practice, distribute a map of the school grounds and assign each group to a specific location. At their school sites, groups use GPS to plot longitude and latitude on the map of the school.

Review Mathematica software and soil analysis techniques. Each group member should be comfortable with one of the chemical tests: nitrogen, phosphorous, potassium and calcium content, and pH.

Field Activity

Once the class is familiar with GPS skills and soil analysis techniques, travel to a local field, park, or land lab. Choose a mapping site for each group. Depending on the size of the sites, each group should analyze data at 10–20 locations within the site. Besides determining exact position using GPS, groups should analyze soil chemical content, and record all data on the laptop computer. Groups can generate 3-D maps using the Mathematica software on the laptops. Groups might

REFERENCES

Books

House, Peggy and Mary Jo Aiken. *Mission Mathematics*. Reston, VA: National Council of Teachers of Mathematics, 1997.

National Research Council. *National Science Education Standards*. Washington DC: National Academy Press, 1996.

Web sites

AGRIS. GPS in agriculture: http://www.agris.com/

ESRI. Geographical Information Systems (GIS) mapping, data, and software: http://www.esri.com/

Fisher Scientific. *GPS Topo Guide*: http://www.fischersci.com/

How Stuff Works. How a GPS receiver works: http://www. howstuffworks.com/gps.htm

Global Position Systems Overview. From University of Texas-Austin's Geography Department : http://www.utexas.edu/depts/grg/gcraft/notes/gps/gps.html

SST Development Group, Inc. GIS data, maps, and applications: http://www.sstdevgroup.com/

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need to gather more data to complete maps. After two hours, gather the class and compile data for the entire park. Groups should each create a 3-D map of the whole park, with a detailed map of its own site.

ASSESSMENT

One method for determining the effectiveness of *Mapping by Satellite* is to give a practical exam: simulate a field in the classroom and have the students conduct the same type of soil analysis and mapping as in the field. Give each student group a "study site," represented by a 24-well microplate. Fill wells with soil samples of varying chemical values. The group analyzes each well, and plots the soil analysis results. Groups take positions, convert readings to latitude, and plot the results on the graph. Students should be able to display their data in a 2-D format (with color-coding representing different variations of the chemical analysis or crop yield) and also in a 3-D map using Mathematica.

Students should also be able to conduct their analysis independently and without instruction. Assess their ability to visualize 3-D maps from 2-D graphs by asking them to match the graphs generated during the practical with the appropriate map of the same "study site".

REFERENCES, cont'd

Trimble Navigation. How GPS and triangulation work: http://www.trimble. com/gps/howworks/aa_hw1.htm

Wolfram Research Inc. Mathematica: http://www.mathematica.com/