# Relative and Absolute Directions

### Purpose

Learning about latitude and longitude
Developing math skills

### Overview

Students begin by asking the simple question: "Where Am I?" Then they learn about the magnetic Earth and the use of compasses and angles. Students also learn about the difference between relative and absolute locations. Throughout this activity, students practice using a variety of math skills.

### Time

From one to five class periods depending on which steps you choose to do

### Level

All levels with some exceptions noted

### Key Concepts

- Relative and absolute direction
- Latitude and longitude
- Angles
- Use of magnetic compass
- Basic mapping

### Skills

- *Distinguishing* between and *describing* relative and absolute directions
- *Communicating* location to another person
- *Describing* locations by using grids
- *Using* a magnetic compass to accurately determine angular direction
- *Developing* basic mapping technique

### Materials and Tools

- Paper and pencil
- Graph paper
- Magnetic compasses
- Drawing compasses (for drawing circles)
- Globes
- Metric rulers and meter sticks
- Bar magnet

### Preparation

None

### Prerequisites

*Beginning levels*: Students should be at the appropriate developmental level to be able to learn about the use of latitude and longitude to find a location.

*Intermediate and advanced levels:* Basic understanding of degrees, angles and coordinate systems.

### Special Note

If your students already understand latitude and longitude, then either you can proceed to the next activity entitled: *Working with Angles* or you can use some or all of these activities to provide a deeper mathematical understanding of relative and absolute directions on Earth.

### Background

The GLOBE program uses GPS receivers to determine the latitude and longitude of GLOBE study sites. However, the ideas of latitude and longitude, coordinates attached to absolute reference systems, or angles from north may be new to many students. This set of activities introduces these concepts.

When you ask students, "Where are you?", they may respond, "At home" or "At school." The answers are in their own local reference frame.

If you use a magnetic compass to determine the direction to a tree that is north of you, you will probably conclude that the tree is to your north. However, if you move east or west by any substantial amount and use the same compass to determine your direction to the same tree, you will find the tree to be to your northeast or your

northwest. Neither the tree nor Earth's magnetic poles have moved, but your compass indicates a different direction to the tree. There is something absolute about the positions of the tree and the poles, but there is something relative about your measurement technique. The starting point moved.

If we impose a gridded coordinate system upon our geographic area of interest or the entire world and number the various lines on the grid, we now have a reference frame in which we can uniquely determine any location independent of the relationship between your location and that of another individual. Latitude and longitude are the names of the values for the coordinate system in which we shall be working for geographic determination of locations with the Global Positioning System.

## What To Do and How To Do It

### *Step 1. Relative Positions: Where am I? (For all levels)*

Have students ask themselves the question, "Where am I?" and have them list words or draw a rough picture of where they are. Lead a class discussion on what defines "where are we?"

Encourage questions and time for reflection on where a person is and how one might explain where anyone was. Good questions for students to ask are: How can you describe your location to another student: in your classroom? in another classroom? in another school in town? in another town? in another country? Did students describe their location using relative or absolute references? Emphasize their reference frames.

### *Step 2. Attempting to Impose a Reference Frame: The Magnetic Earth (For all levels)*

Our planet projects a gigantic magnetic field as if it contained a large bar magnet. See Figure GPS-L-4. Another magnet (like a magnetized needle) will be attracted to our planet's magnetic poles. A magnetic compass contains a magnet which can spin freely and be observed. Thus, magnetic compasses are useful navigational instruments because they allow one to see the direction of Earth's magnetic field, which almost lines up with Earth's north and south poles.

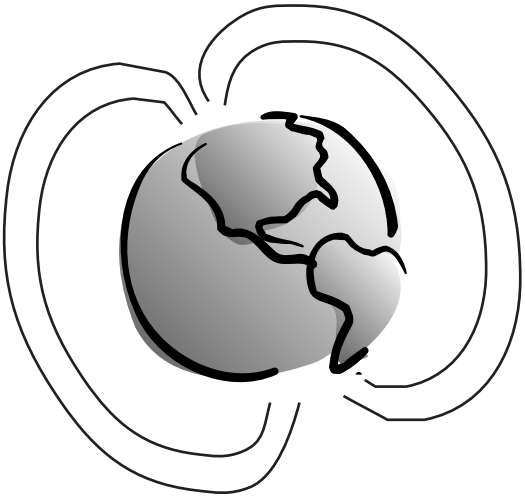


*Figure GPS-L-4: The Earth as a Giant Magnet*

Suspend a bar magnet on a string away from large metal objects and allow the magnet to stop any rotation or spin. Attach the string to the ends of the magnet as shown in Figure GPS-L-5.

Ask students what will happen. The magnet will eventually stop spinning so that its poles are aligned with north and south directions. Students can test the north-south direction by comparing the magnet with a magnetic compass.

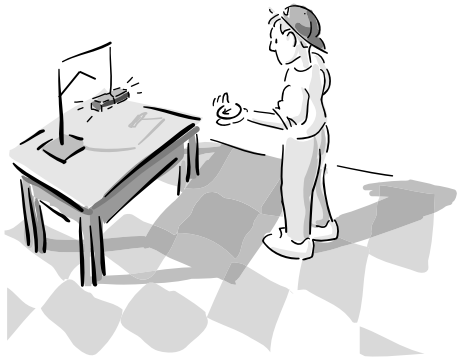


*Figure GPS-L-5: Suspended bar magnet*

To use the compass, hold the compass on your fingers of your outstretched hand and arm. Hold the compass flat relative to the ground so that the needle can move freely, and keep it away from all metal objects. Position yourself so that you can look across the compass through north while waiting for the needle to stop moving. *Do not place the compass near the magnet; it will lessen the effectiveness of the compass.*

### *Step 3. Introductory Compass Angles (For beginning levels)*

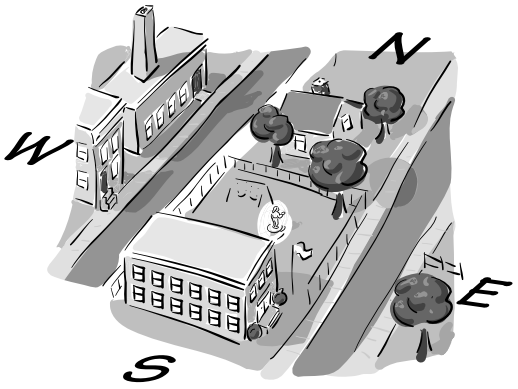
On a blank sheet of paper, record the following observations, using a magnetic compass for direction.

- Record your specific location (e.g., on the big rock outside our classroom window) and the date.
- List all things that are directly to your north (use the compass to find your direction), east, south, and west, then write a descriptive paragraph on each direction.

Chances are that you will not see the variety illustrated, but with a careful observation, you will notice specific differences in each direction.

**Tip.** Be specific about what is seen and the direction it is from you. Also record only permanent foreground and background objects. In areas where there are many things that look similar, try to pick out specific differences.

*Figure GPS-L-6: A panoramic view*




Remember that good scientists are specific in their descriptions and their drawings. They compare and contrast in their observations. Examples would include the following descriptions at two different schools. See Figures GPS-L-6, GPS-L-7a and 7b.

1. The red-brown brick building with the green window frames is due west. To the north of that building is the factory with the tall smoke stack.
2. The area to the east has a single oak tree with a fence extending away from the observer.

Ask questions about the observations to encourage students to compare and contrast.

*Figures GPS-L-7a and GPS-L-7b: View from a school site facing west, view from a school site facing east*

### *Step 4. Intermediate and Advanced Compass Angles (For intermediate and advanced levels)*

You can divide a circle around you into 360 degrees. This is also written as 360°. See the GPS Learning Activity *Working with Angles*. Navigational directions from some location are given as angles around such a circle, with north at the starting place, or 0°. East is 90°; south is 180°; and west is 270°.

**Angular Directions from North**

Your hand can be used to measure directional angles effectively. As illustrated in Figure GPS-L-8, if you extend your arm, make a fist, and then extend your thumb, the width of your hand (with thumb extended) is about 15° (you may need to extend the little finger as well). That means that six of your hands with extended thumbs would fit between north and east. (Each fist with extended thumb equals 15°, because there are 90° between north and east, and 90° divided by six fists is 15° for each fist.)

*Figure GPS-L-8: Using your hand to measure 15°*

Because the angular relationships of each individual's hand will differ slightly, you may find that you have to extend your finger slightly so that six "fists" fit into 90 degrees. You may need to try to measure six "fists" between north and east several times before you consistently get the same number of "fists" on repeated trials. Hold your hand as steadily as possible. Focus on what is at the tip of your thumb, then move your hand so that the back of your hand is now where your thumb tip was. Because you always take your hand with you, remember how you extended your arm and hand so that you can make future angle measurements.

Practice positioning your hand and thumb so that you get a consistent number of "hands" between north and east or north and west. Now record what you see at the end of each hand width. After you feel confident with your measurements go on to the panorama observations below.

### *Step 5. Panorama Observations (For all levels)*

Take a sheet of paper and fold it lengthwise. Cut along the fold, so that you have two long halves of the paper. Tape two of the ends together and mark the four directions on the paper, as indicated in Figure GPS-L-9, so that north is on the two far ends and south is in the middle. Record all observations as drawings on the long narrow strip of paper.

Now that you have had experience with the magnetic compass and with the compass directions, position yourself in the same spot as you did for the compass activity. Draw a panoramic view of what the landscape looks like all around you by making multiple individual drawings for each of the four north, south, east, and west directions. Students can mark all the other directions that fall in between (south southeast, northwest by north), by measuring the angles with their fists.

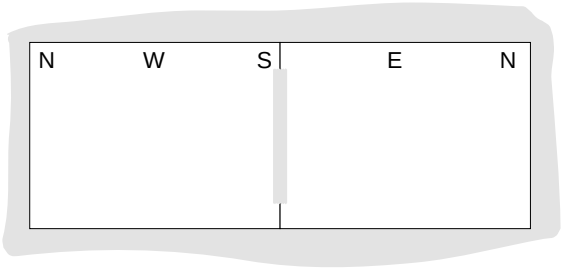



*Figure GPS-L-9: Preparing the strip for drawing a panorama*

To extend this step further, use your fist to measure time. Because the sun moves 15° per hour through the sky, one can estimate the time in hours until sunset by measuring the number of hand-widths from the sun to the western horizon. Knowing your local time of sunset, you can then work backward and estimate your local time without a clock!

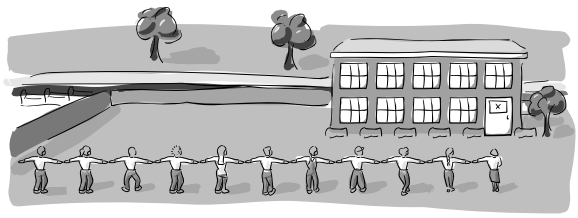


*Figure GPS-L-10: Students lined facing a mark to the North*

### *Step 6. Are the North, South, East, and West Directions Relative or Absolute? (For all levels)*

Outdoors, mark a point about two meters above the ground (for example, crossed strips of tape on a school window), so that you can have the students stand along an east-west line south of the mark. Have the students form a line with the person on the far east due south of the mark. The students should be spaced at arms' length. See Figure GPS-L-10,

In Figure GPS-L-11, the boxes represent individual students. With compass in hand, the first student takes a bearing on the mark and finds that the direction is north and the angle is 0°. The students will then record "0°" in the box, marked "1." Have each student, in numerical order, make an angle measurement between north and the mark. Because all results will be between north and east for the scenario illustrated, all measurement results should be between 0º (north) and 90º (east).

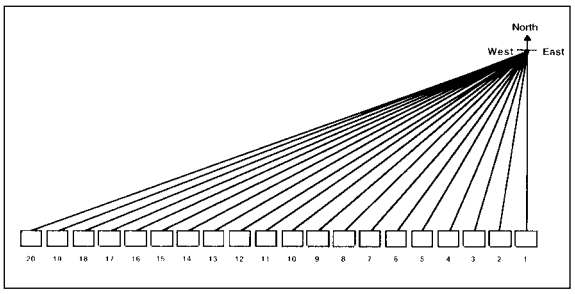



*Figure GPS-P-11: Overhead diagram of students facing a particular mark*

Why did each student get a slightly different measurement? Were they all not looking at the same point? Their compass angles are relative to their individual and different locations.

### *Step 7. Compass Directions Are Relative to Your Location (For all levels)*

For practical purposes, Earth's north and south magnetic poles are fixed close to our planet's north and south spin axes. In the absence of other magnets, a magnetic compass needle aligns itself with Earth's magnetic field. Thus, its needle will point to Earth's magnetic poles. (The Earth's magnetic poles will not move much during our lifetimes.)

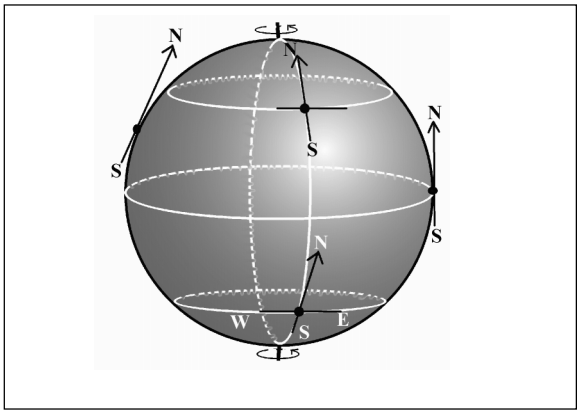



*Figure GPS-L-12: The direction North as perceived at different points on Earth*

Earth's magnetic poles appear fixed. However, an observer on the equator will claim the direction to the north as being along a line tangent to the equator. Another observer who is half way from the equator to the north pole will also claim that the direction north is a line tangent to the globe at his location. However, these two lines are not parallel. See Figure GPS-L-12. Therefore, they are not pointing in the same direction. Get a globe and try this for a variety of different locations around the world. You can see that the direction you call north depends on your location. Therefore, north, south, east, and west are relative directions. These directions are angle measurements in the direction of the magnetic north pole relative to the location from which the measurement is taken.

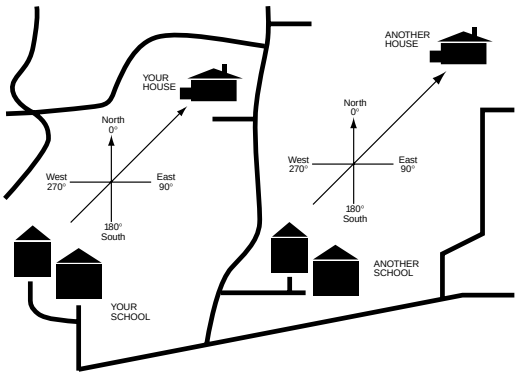



*Figure GPS-L-13*
*Directions from home to school are different for everyone*

**Further background:** Directions are not necessarily unique. What problems does this cause? Navigation between arbitrary locations requires a known point as a fixed reference. Giving directions to listeners who are located at different positions means that they must agree to some point in common before directions can be given. Unique starting and ending points (like trade routes), provide an absolute or fixed reference frame such as a coordinate system placed on a map. Latitude and longitude provide a similar reference frame for our spherical planet.

Use the drawing and map in Figure GPS-L-13 to help students understand relative and absolute directions and positions. See glossary. A full page version of Figure GPS-L-13 is included at the end of this Learning Activity. You may make duplicates for student use.

Describe how to go from your school to your house. Then describe how to go from another school to another house. Then ask, what is the difference?

**A riddle about absolute directions:** Someone builds a house. All of the outside walls of the house face south. A bear walks up to the house. What color is the bear? (Answer: White - if all sides of the house face south, then the house must be at the North Pole. The only bears in the Arctic Circle are polar bears.)

### *Step 8. Describing a Location (for all levels)*

We wish to introduce absolute reference frames for describing locations. Students will expand upon past activities to answer the question "Where am I?" or "Where is something?" and will learn that they must specify the "where" with sufficient clarity so they can communicate their position unambiguously to someone else. We ask students to provide directions relative to some agreed-upon reference or some coordinate system instead of relative to themselves. Cartesian coordinates (x,y axes in geometry and algebra) and latitude and longitude on the globe provide such a system.

Place two students back to back, each with checker boards, so that each cannot see the other's board. Give them two checkers (tokens) and have one place the tokens anywhere upon the board. Without imposing further rules, have that student describe to the other student where to place the token, so that each token is in the same position on each board. Repeat the process beginning with the second student.

*Figure GPS-L-14*
*Describing checker locations*

Lead a discussion on the communication between the two students. How did the students choose to communicate the locations of their tokens? What determined the clarity and difficulty of their communications?

### *Step 9. Numerically Describing a Location (for intermediate and advanced levels)*

Label a piece of graph paper or a drawn grid as shown in Figure GPS-L-15, Have students find positions communicated as follows: (1,2), where the first number describes the distance to move to the right from zero on the horizontal axis and the second number describes the distance to move up along the vertical axis.

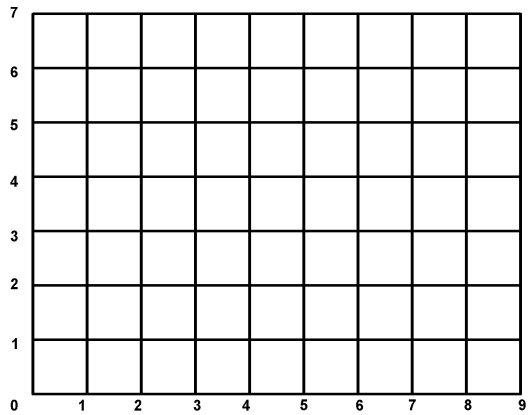



*Figure GPS-L-15: Label a sheet of graph paper*

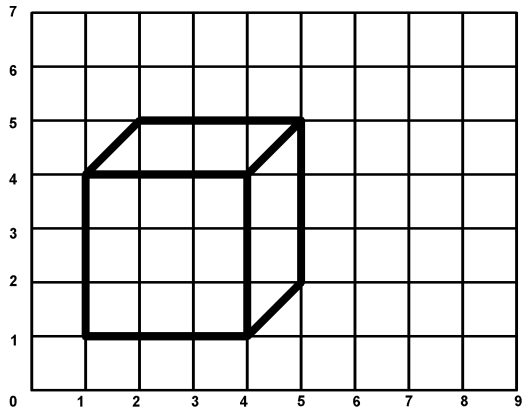



*Figure GPS-L-16: The resulting simple picture*

Then, have students draw a simple picture from the following lines between the given sets of positions. See Figure GPS-L-16.

| | | |
|---|---|---|
| (4,1) to (4,4) | (4,1) to (5,2) | (5,2) to (5,5) |
| (1,4) to (1,1) | (1,1) to (4,1) | (1,4) to (4,4) |
| (1,4) to (2,5) | (2,5) to (5,5) | (4,4) to (5,5) |

Discuss what information is needed to communicate points and drawings. For example, each line required information about a starting point and an end point.

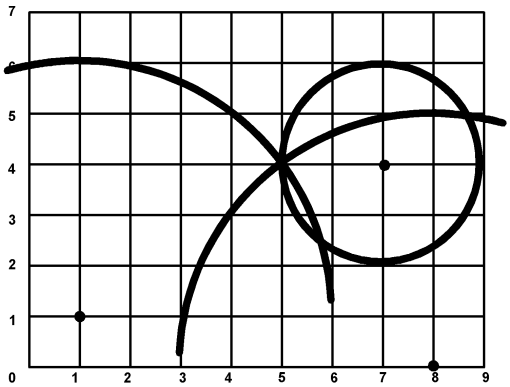



*Figure GPS-L-17: Cartesian coordinates defining arcs*

On a new piece of gridded paper, go to position (7,4), and draw an arc with a drawing compass that has a radius of two units. With position (1,1) as the center, draw an arc with a radius of five units that intersects the first arc. Finally, draw a third arc, with a radius of five units and which has a center at (8.0). Where do they intersect? How many arcs are needed to determine a point.

Suppose that the Cartesian coordinates in Table GPS-L-1 were mapping a portion of ocean and that the side of each square was the distance it

*Table GPS-L-1*

| Signal travel time | | |
|---|---|---|
| **Ship** | **Location** | **milliseconds** |
| Alexandria | (0,0) | 4.0 |
| Corsica | (1,5) | 2.0 |
| Hsuchou | (6,3) | 3.5 |

*Ship location and time for Bainbridge's signal to travel to each ship*

*Table GPS-L-2: Places on the Globe*

| Latitude | Longitude | Name |
|---|---|---|
| 36°N | 139°E | _____ |
| 60°N | 30°W | _____ |
| 27°S | 109°W | _____ |
| 90°S | 0°E | _____ |
| 90°S | 180°W | _____ |
| __ | __ | Your location |
| __ | __ | Your opposite location |

takes a radio signal to travel in one millisecond. There are three ships at sea, the Alexandria is at (0,0), the Corsica is at (1,5), and the Hsuchou at (6,3). Each ship receives a distress signal from a fourth ship, the Bainbridge. The time that it took the Bainbridge's distress signal to travel to the three potential rescue ships will help the ships locate Bainbridge's position. Can you find the distressed ship? (Measurement of signal travel times forms the basis of radar and GPS.)

### *Step 10. Describing Geographical Locations (for intermediate and advanced levels)*

On a globe, the east-west lines are lines of constant latitude and the north-south lines are lines of constant longitude. Have students discuss how they are similar to and how they are different from the lines they found on the Cartesian coordinate system. Find the locations listed in Table GPS-L-2.

Take a globe and find your location. Estimate values for your latitude and longitude from the globe. Now find the point on the globe opposite your location and estimate its latitude and longitude. What are the relationships between the latitude and longitude coordinates for these two opposite locations?

**Note:** Steps 8, 9, and 10 present concepts similar to those in *Odyssey of the Eyes Learning Activity* in the *Land Cover/Biology Investigation.*

## *Adaptations for Younger and Older Students*

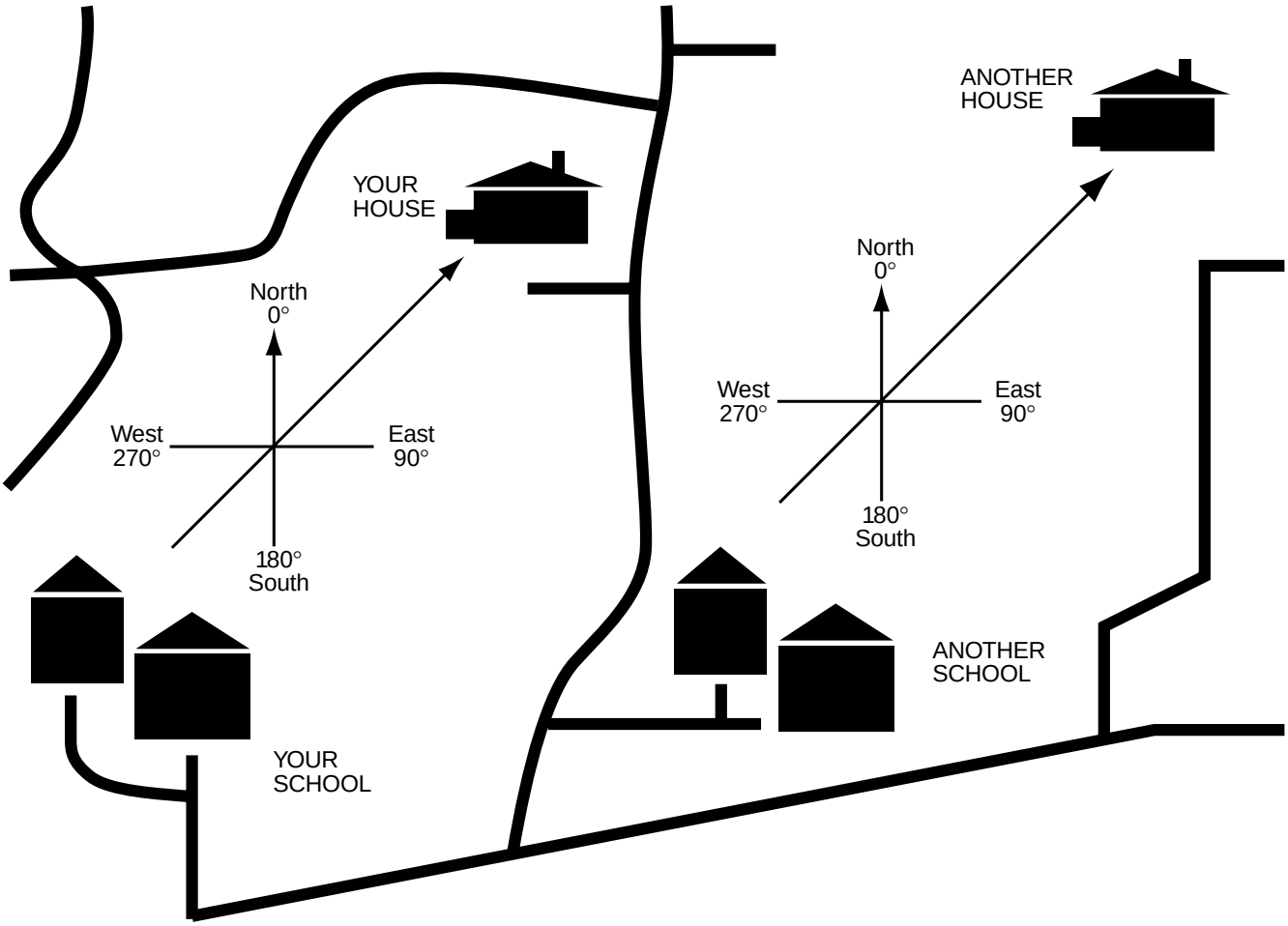
Qualitative descriptions of measurements may be more appropriate for younger students. For example, describing a compass direction as being "northeast" may be clearer than "45° from north." More quantitative and analytic techniques may be appropriate for older students. For example, they can use the Pythagorean Theorem to determine distances between locations in a flat, gridded coordinate system.

## *Student Assessment*

Have students identify various cities or geographical features using latitude and longitude. Give them a list of cities and have them determine latitude and longitude for each. Also have them find distances between geographical locations.

# GPS Investigation

## School Site Location Map Graphic



# GPS Investigation

## Site Location Data Work Sheet

You will need at least one copy of this GLOBE GPS Data Sheet per GLOBE site. After making your field GPS measurements and averaging the position data, note your results on one of the GPS Data Submission Sheets, then submit your data to GLOBE. You can do this by accessing the GPS data entry page under the main GLOBE page **(http://www.glove.gov)** on the World Wide Web. You will be submitting the determined average location for each of your sites (Atmosphere, Land Cover, Biology, Hydrology, Soil Characterization, and Soil Moisture Study Sites and your school). The data submitted should be rounded to the nearest **0.01 minutes** as displayed on your GPS receiver.

### *Type of Site*

(Atmosphere, Hydrology, etc.)

### *Site Description*

(25 characters or less)

### *Averaged Latitude*

(Whole Degrees, Decimal Minutes N/S)

### *Averaged Longitude*

(Whole Degrees, Decimal Minutes E/W)

### *Time of 1st Observation*

Hours: Minutes: Seconds in UT

### *Type of Receiver*

Magellan Trailblazer XL & UNAVCO number

or

Manufacturer model number and serial number