Think about It

Student Conceptions

The most common responses that students offer to the first question about locating your position on the Earth's surface include:

- Use latitude and longitude from a map.
- Use a GPS receiver to get latitude and longitude.
- Use satellites to track your position.
- Describe and measure your position relative to something else, like a building or a large tree.

Students typically respond to **Question Two** by referring to the method they outlined in **Question One**, and they usually mention taking measurements over time.

- Measure your latitude and longitude over time.
- Take GPS measurements of latitude and longitude over time.
- If your position relative to a stationary or known object changes over time, then you have moved.

Answer for the Teacher Only

To locate your position on the Earth's surface, you could measure your position relative to known features, use maps or road maps, or use objects in the sky (stars, planets) for reference.

> ### Assessment Tool
>
> **Think about It Evaluation Sheet**
> The **Think about It Evaluation Sheet** will help students to understand and internalize basic expectations for the warm-up activity.

To determine whether your position on the Earth has moved, you would have to make observations or measurements over time. You would have to look for evidence of change in position relative to known features.

Investigate

Part A: Data from the Global Positioning System

1. **a**) The arrow on the map shows the speed and direction of the station.
   b) Northwest.

Teaching Tips

Circulate from group to group asking questions to help them address the questions being asked.

Use the **Blackline Master Plate Tectonics 1.2** to make an overhead of the map on page 65 for discussion. Highlight the location of GPS recording station WES2. Also point out recording stations located close to your community for reference in **Part A: Step 8**. Explain to students that the arrow in the lower left corner of the map is a scale which shows the length of a "20 mm/yr" arrow.

Assessment Tool

The **Investigate Notebook Entry-Evaluation Sheet** is designed to help students get a sense of the expectations for *EarthComm* notebook entries. You might wish to review the criteria if this is the first time that students use the sheet.

c) The station is moving less than 20 mm per year because the arrow at WES2 is shorter than the 20 mm per year arrow in the scale.

d) No. The arrows are of varying lengths, which indicates that the stations do not all move at the same speed.

e) No. The arrows point in different directions at different stations.

f) The arrows in North America point in various directions, but most point in directions not much different from west, so the general or average direction is close to being to the west.

2. a) The time series shows a little over three years of data.

b) Measurements were recorded only at certain times. The data points on the time series are discrete, not continuous.

3. a) The northward movement is 4.3 mm/yr, or 0.43 cm/yr.

Teaching Tips

If you find that your students are struggling with interpreting the graphs on page 66, you may wish to make an overhead transparency of the **Blackline Master Plate Tectonics 1.3** (a copy of the graphs on page 66). Review the following with students in a class discussion:

- What does each of the axes represent?
(The horizontal axis is time from 1996 to 1999, and the vertical axis is change in position in millimeters.)
- What are the vertical bars on the graph?
(The vertical lines that surround each data point (the small dot in each vertical line) are error bars to indicate the margin of error associated with each measurement. An analogy that you can make that is familiar to most students is the "margin of error" in a political poll, such as "45% plus or minus three percentage points." The error bars on such a poll would run from 42% to 48%.)
- What does the long line on each graph represent?
(The long line represents the "best fit" line through all of the data points. The slope of the line can be used to determine change in position per year. For example, WES2 North Offset begins at about –9 mm and ends at about 6 mm. That is a (positive) change in position of about 15 mm over about 3.4 years, or about 4.4 mm per year (which is very close to the speed recorded above the graph). This provides an opportunity to integrate mathematics and science.)
- Why do the graphs not start at zero?
(All positions were plotted in reference to a particular time in 1997 that scientists agreed upon.)

After students complete the activity, you might point out or ask students if they have observed several interesting features of the map on student page 65 (**Blackline Master Plate Tectonics 1.2**).

- What do the lines in the Atlantic Ocean represent?
(The lines represent the boundaries of the lithospheric plates.)
- What do you notice about the coordinates for longitude on the map?
(They are provided as degrees east of the Prime Meridian (range of 0 to 360°).)

4. a) The movement of WES2 is 14.4 mm/yr in a westward direction, or 0.144 cm/yr.

5. a) WES2 has not stayed at the same elevation over the last several years. The data points fluctuate over time.

6. The station did not move at a constant speed. The data points fluctuate around the best-fit line on the graph.

7. a) No, not if the individual measurements are accurate within the error bars shown and are representative of the actual motion, because some of the measurements have error bars that lie outside the best-fit line. If there are unknown inaccuracies in the measurement data, however, it is still possible that the speed was constant.

   b) You could obtain a similar record for a nearby station. If the nearby station is not too far away from the given station, then if the measurements are accurate you would expect the two records to look very similar. If they do not show a strong correlation, then it is likely that some unknown effect was causing scatter in the data.

8. Students (or you, ahead of time) will have to obtain the data. Go to the *EarthComm* web site, which will direct you to links where the data is available.

Teaching Tip

If you have the materials available, an interesting extra credit or extension exercise would be to have students use GPS receivers to locate their latitude and longitude. Provide students with typed instructions on how to use a GPS receiver and allow them to pair up and go outside for 10–15 min to take readings over several days.

Part B: Data from a Computer Model

1. Many students may need to be reminded how latitude and longitude are marked on a topographic map. For additional information, see the USGS pamphlet that is sent free whenever you order topographic maps. Students must convert the longitude from the degrees–minutes–seconds format to a decimal format in order to enter the location of their community into the web site for the plate motion calculator.

2. Copy the world map of lithospheric plates for your students (see the **Blackline Master Plate Tectonics 1.1**). They can use this map in **Step 5** as well.

3. **a) – b)** Provide data from the Relative Plate Motion Calculator (or allow student access). Go to the web site, which will provide a link to the web site, Relative Plate Motion Calculator.

A sample calculation for 44.5° north latitude and 110.5° west longitude is shown below.

NUVEL-1A Calculation Results
Calculation results are as follows:
Relatively fixed plate = Africa
Relatively moving plate = North America
Latitude of Euler pole = 78.8°
Longitude of Euler pole = 38.3°
Angular velocity = 0.24 degree/million years
Latitude inputted = 44.500000°
Longitude inputted = -110.500000°
Velocity = 2.19 cm
Direction = 277.03°

d) Results from the plate motion calculator may not match the results from the GPS time-series station.

e) GPS data provide vertical motion, and the plate motion calculator provides only horizontal motion.

This exercise integrates critical thinking and mathematics. Students will use the speed and direction of plate motion (shown as an azimuth, or degrees clockwise from north) to map the changing position of their community over time. Alert students to the fact that on the plate motion calculator, direction is given in degrees clockwise from north, known as azimuth. For example, 90° is directly east, 180° is directly south and 270° is directly west. Students will need a photocopy of a portion of their local topographic map to plot the data points. An 11 x 17 inch copy will work best.

Students look at the change of position over a longer time span (tens of millions of years). A map of the United States (or the **Blackline Master** of the map of relative plate motions) should be used.

Teaching Tip

Web sites such as MapBlast often provide the latitude and longitude of a street address. Type in the address of your school at www.mapblast.com.

Reflecting on the Activity and the Challenge

Use this opportunity to direct students back to the **Chapter Challenge**. Although students may have varying levels of knowledge about plate tectonics, this activity has enabled them to investigate how technology (GPS and computer models) is used to track the motion of the Earth's crust. They now know that the Earth's crust is not stationary, but moving! The **Digging Deeper** reading section will help students to understand the sources of the data they have explored in this activity.

Digging Deeper

Assign the reading for homework. The questions in **Check Your Understanding** (page 74) can be provided as a homework assignment.

Assessment Opportunity

Use (or rephrase) the questions in **Check Your Understanding** for a brief quiz to check comprehension of key ideas and skills. Use the quiz (or a class discussion about the questions in the textbook) to assess your students' understanding of the main ideas in the reading and the activity.

A sample quiz is given below.

1. Draw a simplified cross section through the outer part of the Earth. Label the following: mantle asthenosphere, mantle lithosphere, continental crust, and oceanic crust.
2. How did the formation of magnetic striping along the ocean floor help to validate the theory of plate tectonics?
3. What is the name for the satellite-based system used to accurately locate points on the Earth's surface?
4. Why is the mid-ocean ridge not straight?

Assessment Tool

Check Your Understanding Notebook Entry-Evaluation Sheet
This evaluation sheet is used to help you evaluate the extent to which students understand the key concepts explored in the activity and explained in the **Digging Deeper** reading section.

Check Your Understanding

1. The lithosphere consists of the crust (oceanic or continental) and the uppermost and coolest part of the mantle, which together move as a rigid body, without flowing. The asthenosphere is the hotter part of the mantle below the lithosphere. The asthenosphere moves by flow (internal deformation), and is the part of the mantle that participates in the large-scale convective motions associated with plate tectonics.

2. Global Positioning System.

3. From a number of special satellites that orbit the Earth.

4. Because the GPS was developed only recently.

5. As new oceanic crust is created symmetrically on the two sides of a mid-ocean ridge and is rafted away from the ridge, reversals in the polarity of the Earth's magnetic field are recorded in the magnetite-bearing rocks of the crust. This so-called remanent magnetism either adds to or subtracts from the present magnetic field of the Earth, resulting in symmetrically arranged belts of higher-than-average and lower-than-average magnetic field strength of the ocean-floor rocks.

6. The offsets of the segments of a mid-ocean ridge are transform faults, along which the two plates on either side of the ridge slide past one another. The transform faults do not extend beyond the ends of the ridge-crest segments. The pattern of ridge-crest segments and transform faults probably is inherited from the time the ridges were first formed by rifting of a continent.

Understanding and Applying What You Have Learned

Stress that answers to the questions and related explanations are to be based on evidence.

1. Answers will vary, depending upon where students live.

2. This question makes students think about the temporal scales over which plate tectonics operates and the extremely slow speeds of plate movement.

Teaching Tip

You may need to briefly review the concept of scale as well as conversion factors with your students to make sure they are using the proper units. Ask students how much their community has moved in their lifetime, over 100 years, 1000 years, etc.

3. The GPS provides evidence of the motion of the Earth by allowing scientists to make very precise and accurate measurements of the position of an object on the Earth's surface. When the position of the object (GPS receiver) is tracked over time, GPS data reveal that the object moves.

4. One advantage to using GPS technology to gather evidence of plate motion is that it is so accurate. Plates move extremely slowly, but the precision of GPS allows even slight movements over a short period of time to be measured.

5. Studies of magnetism of rocks on the sea floor provide evidence that the surface of the Earth moves over time by revealing a symmetrical pattern of magnetic reversals in rocks on each side of the mid-ocean ridge. The similar ages and magnetic patterns in the rocks on opposite sides of the ridge indicate that the sea floor has been spreading apart over time.

6. GPS time-series plots suggest that the directions and speeds of plate motion has not been constant over time.

7. Students should refer to the world map of plates in answering the following questions:
   a) The plates have been named for continents and ocean basins.
   b) Students should note that the North American plate is bordered by the Pacific, Cocos, African, Caribbean, Eurasian, and South American plates. The North American plate is moving away from plates that lie to the east of it.
   c) The differences in motion of the plates might do one of three things, depending on the sense of relative motion. Divergent motions might crack or fracture the lithosphere; convergent motions might cause one lithospheric plate to move down under another; and parallel motions might cause one plate to slide past another.

Preparing for the Chapter Challenge

The purpose of this section is to have students pull something from the activity that can be used for their end-of-chapter report (the **Chapter Challenge**). Rather than waiting for the end of the last activity to solve the **Chapter Challenge**, students will be producing work all along the way that helps them meet the challenge. Remind students of the criteria for judging their work that were discussed at the start of the chapter, where the **Chapter Challenge** was presented.

Inquiring Further

1. Technology used to detect plate motions
This open-ended requirement is useful for helping students to better understand how the GPS works. Explore these web sites and develop some questions to guide further student inquiry at a level appropriate to your students, or to help students to supplement their **Chapter Challenge** reports. Explore how the GPS allows plate movement to be measured. Excellent web sites that describe how the GPS works are given on the *EarthComm* web site.

2. Investigating scales of motion
The goal here is for students to gain a better sense of the speeds of plate motions by comparing them to something more familiar. Plate motion is extremely slow. Make a list of other things you know about (or have heard about) that move or take place slowly. Possible examples include growth of fingernails, grass, tree height, tree-trunk diameter, and so on. Find out how fast they move. Compare the speed of these motions to the speeds of movement of plates.

3. Study animations of plate motions
This animation allows students to see the big picture. Challenge students to figure out how much faster than real time the movie plays. Visit the *EarthComm* web site for web links to animated images of the motions of lithospheric plates. To describe how the motions shown in the animations match your analysis from this activity, the following books provide further information about the motions of plates and the theory of plate tectonics:

The New View of the Earth by Seiya Uyeda, 1978 by W.H. Freeman and Co.

Global Tectonics by Philip Kearey & Frederick J. Vine, 1996 by Blackwell Science, Ltd.