Enhancing the Spatial Skills of Non-Geoscience Majors Using the Global Positioning System

Eileen Anderson Herrstrom
Department of Geology
University of Illinois
1301 West Green
Urbana, Illinois 61801
herrstro@uiuc.edu

ABSTRACT

Global Positioning System (GPS) receivers are a type of scientific equipment that is accessible to the general public and potentially capable of motivating students to learn. Inexpensive receivers provide students with experience aimed at developing spatial awareness and practicing mathematical skills as they acquire data and analyze it through calculation and mapping. Here I report on an experimental use of GPS in a small honors class, with the goal of eventually applying it more broadly in introductory courses. GPS was incorporated into an existing physical-geology course in the form of six laboratory and homework exercises (for example, marking positions with latitude and longitude, closing a triangle, drawing maps) with positive results. Students enjoyed using the technology, appreciated working outside the classroom, and learned the basics of GPS, while developing directional and spatial awareness and quantitative skills in trigonometry, graphing, and use of computer spreadsheets. Successful introduction of GPS into this small class augurs well for its use in larger general-education courses.

Keywords: Apparatus; areal geology – maps; areal geology – general; education – computer-assisted; education – geoscience; education – undergraduate; miscellaneous and mathematical geology.

Introduction

Students in an introductory physical-geology course used the Global Positioning System (GPS) in exercises designed to enhance spatial awareness and to acquire real data for analysis by hand and by computer spreadsheet. Use of GPS is becoming widespread and may already be familiar to some students through consumer products, such as navigation systems for new cars, specialized sporting goods (for example, fish finders), or popular TV series (for example, *The X-Files*). Consequently, GPS is a non-threatening technology that can be used to introduce latitude, longitude, and navigation techniques, the difference between accuracy and precision, statistics (such as average, range, and error), and computer applications. In addition, it may serve to motivate students in a general-education course and add a field component to classroom-based instruction.

The Geology Department at the University of Illinois decided in fall 1998 to purchase GPS equipment primarily for use in introductory classes to address the types of geographic illiteracy often observed among my students, such as uncertainty about which hemisphere they live in, which lines are latitude and which are longitude, and why lines oriented east-west are labeled with "N" or "S." Part of the problem is that few people have personal experience with latitude and longitude. GPS can supply such experience.

We opted to acquire multiple autonomous GPS receivers with relatively low accuracy in order to accommodate many users in large classes. For the applications we envisaged, we could accept errors of up to 100 meters induced by the deliberate scrambling of the signal known as Selective Availability (SA). Recently, however, this scrambling was ended, and autonomous GPS receivers now register positions to within 10 meters. We purchased our equipment in spring 1999 and used it in class for the first time the following fall; thus, some of the difficulties we encountered due to the scrambling should no longer cause problems.

My use of GPS differs from that of most others in the literature in its focus on demonstrating basic concepts to students in general-education courses. Among geographers, GPS is more commonly used as a tool linked to a geographical information system (Brown, 1999; Wentz, 1999), while geologists concentrate on teaching field techniques to geology majors (Trexler, 2000; Philpotts and others, 1997) or use GPS primarily to locate field sites. In this article, I take a broad view of the term "quantitative skills," including not only computation and mathematical problem solving but also spatial skills (visualizing in three dimensions), geographic literacy (sense of direction and familiarity with latitude and longitude), and computer literacy (use of spreadsheets for repetitive calculations and for graphing), as well as the use of positioning technology itself. Such activities build upon the national standards in earth science for precollege students, by requiring students to apply technology appropriately and understand the relationship between technology and science (National Research Council, 1996).

GPS exercises were first implemented as part of a physical-geology course for students in the Campus Honors Program. We intend ultimately to use GPS in our largest general-education class, which enrolls approximately 700 students per semester, but decided to experiment initially on a smaller scale. The honors class consisted of eight students – three freshmen, two each of sophomores and juniors, and one senior, which is similar to the distribution in the large class of about 50% freshmen, 30% sophomores, and 10% each of juniors and seniors. Students in the honors class were majors in fine arts, liberal arts, business

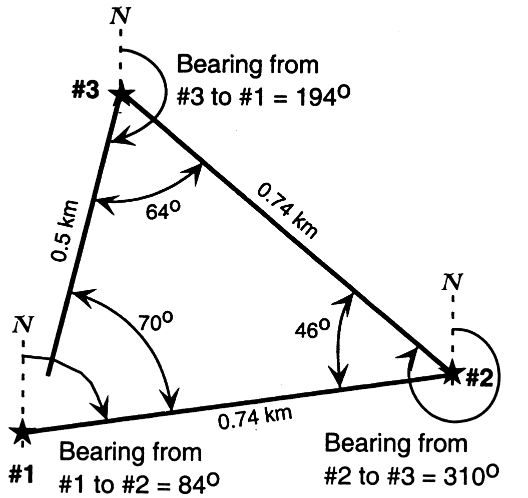

Figure 1. Students plot bearing and distance data for pairs of points from a set of three. If the triangle does not close, as shown here, they must explain why it does not, in terms of the GPS errors. If it appears to close, they must prove closure using trigonometry.

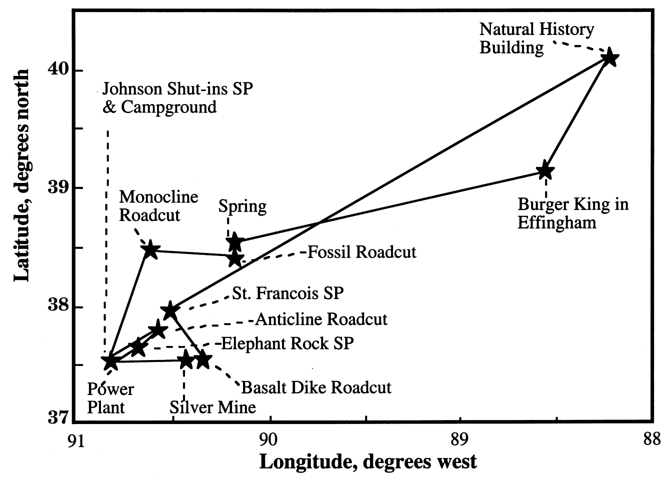

Figure 2. A student map based on a field trip to the Missouri Ozarks. Position data were downloaded from the receiver, imported into a Microsoft *Excel* spreadsheet for plotting, and annotated using *Excel's* drawing functions.

administration, and engineering; in the large class, majors come from every college in the university. Thus, we tested the GPS teaching unit with students who are only partially representative of those who will eventually use the equipment.

GPS Exercises

GPS was incorporated into the course in the form of six laboratory-based exercises. None of the material was covered in the lecture, which was taught by a different person. I expanded the first laboratory, which previously had not used the entire period, to include a brief introduction to GPS and reduced the number of laboratories on rocks and mineral from five to four to provide a full session for making maps with GPS. The remaining GPS exercises were assigned as homework. The mixture of classroom and homework activities effectively integrated GPS into the course without extensive revision.

Around the quad with GPS – This exercise, conducted during the initial laboratory period, provided most students' first exposure to GPS. I showed them the main display screens and some basic functions, then sent them outside to walk around the main university quadrangle. They filled out a worksheet that contrasted the changes in latitude and longitude on an east-west vs. a north-south traverse and recorded the positions of the quadrangle corners. After returning to the classroom, they compared results and found differences due to the accuracy limits of the receiver. They calculated the lengths of a minute of latitude and a minute of longitude, in meters, based on their corner positions. Finally, they explained the difference in lengths with reference to great and small circles on the globe. Such position data collected by students could also be used to illustrate the concepts of accuracy and precision and to calculate the average, range, and standard deviation.

Closing a triangle – For one homework assignment, I provided students with the latitude and longitude of three points on campus. They could choose to enter the coordinates into a GPS receiver and use the GOTO function to find the points, or they could navigate to each point freely by watching how their position changed. They took distance and bearing measurements between successive pairs of points and made a scale drawing of their measurements (Figure 1). If the graphical results appeared to close, students used trigonometry to prove closure analytically. If the triangle clearly did not close, students explained their graphical results in terms of measurement errors in their data.

GPS and maps – In preparation for making maps during a laboratory period, students brought GPS receivers on a weekend field trip to the Missouri Ozarks, with instructions to record points of their choosing. They took these instructions to heart. More than once, the trip leaders were ready to start discussing geology while the students were still busy naming their points. Some students marked only the "official" geologic stops, but others conscientiously recorded even the lunch stops. During the next lab period, students downloaded the data to the computers and imported it into a spreadsheet. The lab notes included detailed directions on how to modify the data for graphing (for example, GPS receivers register west longitude as a negative number, so students deleted the minus signs, then ploted x-values in reverse order for correct longitude). For some students, this exercise provided an introduction to the power and possibilities of computer spreadsheets. Students produced individual maps, polished them (for example, by adjusting the scale), and labeled their waypoints (Figure 2). One unanticipated benefit of the mapping exercise was that students reviewed the field-trip stops with each other as they annotated their maps.

Other exercises – The rest of the exercises provided background, practice, or in-depth study. Two

URL	Contents
http://www.trimble.com/gps/index.htm	Tutorial with animation
http://www.garmin.com/whatsNew/adventures.html	Tutorial and short stories about GPS
http://www.gps4fun.com/main_tutorial.html	GPS basics and descriptions of various products
http://www.gpsworld.com/issue0.htm	Articles about GPS projects
http://mapping.usgs.gov/mac/isb/pubs/factsheets/fs06299.html	Extensive information, plus links to US National Geodetic Survey and US Coast Guard Navigation Center
http://www.igeb.gov/	Homepage of the Interagency GPS Executive Board which manages the entire system

Table 1. Addresses and brief descriptions of web sites with GPS tutorials, narratives, general information, or links to other sites.

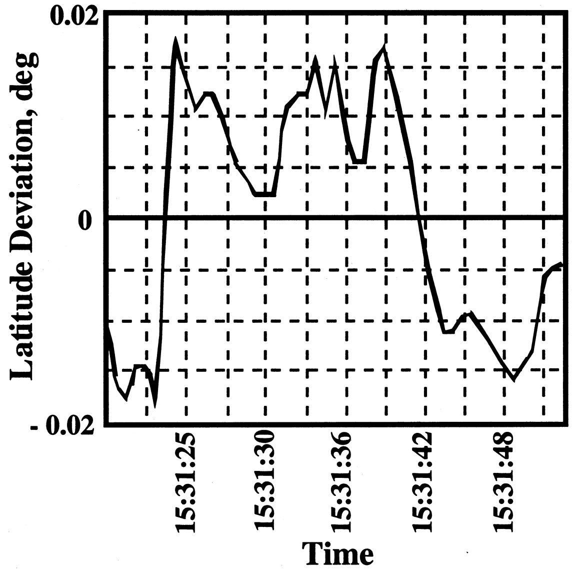

Figure 3. Latitude correction using differential GPS. Deviations from the average of latitude readings from a fixed receiver are used to correct latitude readings from a roving receiver. This procedure reduced SA-imposed errors from tens of meters to meters and should result in even more accurate positions now that SA has been eliminated.

homework assignments early in the semester developed familiarity with GPS as students worked through a tutorial on one of several available web sites (Table 1), studied the operator's manual, and practiced using receivers that had been placed on reserve in the Geology Library. I redesigned a campus "rock hunt" so that students navigated to the various sites with GPS. Finally, an individual student who wanted to delve deeper used differential GPS to obtain more accurate position data (Figure 3).

Discussion

In this initial test of teaching GPS to a small group of students, I did not try to measure outcomes quantitatively, but my observations and their informal feedback suggest that students did learn from using the technology. After the introductory exercise, one student reported that she was no longer confused by the lines on the globe. When we discussed students' attempts to navigate to points around campus, they recognized the problem of compounding errors. The triangle exercise led to a discussion of how position is triangulated – the basis of GPS – and thence to students' acknowledgment of the utility of mathematics, even of the dreaded trigonometry. During the field trip, students paid attention to compass directions and relative locations, which previous classes had rarely done. Finally, none of the students had used spreadsheets for calculation or graphing, so they were impressed by their own success in manipulating data and producing maps based on the field trip.

Student reactions to the GPS exercises were mostly favorable; the negative comments have been helpful in revising the exercises. Positive comments include:

> "GPS helped me become more motivated in my studies,"
>
> "marking waypoints at campus sites seemed like a good and practical way to use GPS and apply it to real life activities outside of the lab,"
>
> "creating the maps was really useful, and it was neat to combine the units with computer software," and
> "it's really cool that we are actually getting live readings from satellites!"

Negative comments focused on problems:

> "frustrating when all the waypoints wouldn't work, due to error," and
>
> "I would recommend a more in-depth introduction to latitude and longitude. I haven't really dealt with these terms since junior high."

GPS must have caught students' attention because they expressed interest in the technology beyond merely completing their assignments. Including mathematics in physical geology was a secondary goal in this class, but clearly the potential exists for greatly increasing student exposure to mathematics through GPS.

Student suggestions led to improvements in the exercises and illuminated several pitfalls to avoid. It is important to provide the most accurate position data possible when asking students to navigate to specific places. Accurate positions can be obtained by averaging track data collected for about 30 minutes at a single spot, but with the end of SA, accuracy should be a much smaller problem in the future. It is crucial that students understand how to read the compass page for navigation to a point because the GPS instrument differs from an ordinary compass. In particular, they should know that the direction is valid only while they are moving and that they can never walk the distance down to zero. The class reminded me to check batteries frequently, especially for receivers on library reserve. Finally, whenever using computers in class, it is prudent to have a backup plan, for example, having extra computers available in case one crashes or having prepared data files should downloading fail.

The original impetus for using GPS was to develop the spatial and directional awareness of students in our largest general-education course. This will require much more modification to the syllabus than was necessary for the honors course and, with 25 to 35 laboratory sections per semester, careful attention to logistics. GPS will be introduced first into only a few sections of the course, whereas the other sections will continue to be taught without GPS, that is, with minimal emphasis on geographic literacy. This will allow us to determine the practicality of adding GPS to a large-enrollment course and to assess the effectiveness of using GPS to teach spatial skills to students who are not in the honors program. If the results confirm our preliminary findings from the honors course, we will subsequently implement GPS for the entire class.

Conclusion

A set of new GPS receivers was used on a trial basis in a small class for honors students. Our general intentions were to incorporate GPS into an existing physical-geology course, in preparation for using it more broadly, and to engage student interest, thereby motivating them to learn. Educational goals for the project were to enhance spatial abilities, teach the fundamental concepts of positioning technology, add an element of field work to the class, and increase the utilization of mathematics. GPS exercises were successfully integrated into the course without significant changes to the syllabus. Students enjoyed using the technology, appreciated getting outside, and learned the basics of how the system works. They were required to use mathematical knowledge, such as trigonometry, that some had not needed for years, and the potential exists to include much more quantitative reasoning in physical geology by using GPS. Success at this small scale encouraged us to proceed with applying GPS on a larger scale in 100-level courses.

Acknowledgments

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About the Author

Eileen Herrstrom is a teaching associate and academic development professional at the University of Illinois. She received her BA from Augustana College, MS from Stanford, and PhD from the University of Iowa.

Food for Thought

The impact of Darwin's views on modern thought has been so profound that it is extremely hard for us, today, to imagine how people thought about the history of life before the publication of *The Origin of Species* in 1859. We think of every aspect of our lives in terms of phrases such as 'the survival of the fittest', 'the struggle for existence', or even 'it's evolved'. Darwin's position of eminence is, in fact, so great that it transcends the immediate particularities of commemoration. Scientists such as Faraday and Newton have appeared on British banknotes: not so Darwin, the achievements of Newton and Faraday can be easily grasped; the difference that they made is palpable.

Darwin's victory, on the other hand, has been so complete that we cannot imagine a time before Darwin, so commemoration seems irrelevant. Darwin is just there and will be so forever, without our having to erect statues in his honour. No splendid thoroughfare or elegant London square need carry Darwin's name: his memory is assured.

Henry Gee, 1999,
In search of deep time: Beyond the fossil record to a new history of life:
New York, The Free Press, 267 p. (from p. 115-116)