Isn’t That Spatial: Coordinate Systems: Integrating Geography and Mathematics

--Joseph J. Kerski

Teaching about coordinate systems provides excellent means of integrating geography and mathematics, the incorporation of fieldwork, and paves the way for understanding GPS and GIS in education. A coordinate system is the system used to reference, or locate, everything on the Earth’s surface in x and y space. The system used to portray a part of the spherical Earth on a flat surface, whether a paper map or a computer screen, is called a map projection. Each map projection used on a paper map or in a GIS is associated with a coordinate system. To simplify the use of maps and to avoid pinpointing locations on curved latitude-longitude reference lines, cartographers superimpose a rectangular grid on maps. Such grids use coordinate systems to determine the x and y position of any spot on the map. Coordinate systems are usually identified by the name of the particular projection for which they are designed.

Because no single map projection is suitable for all uses, there are a myriad of coordinate systems in use on the Earth’s surface. Some are worldwide or nearly so, while others cover entire countries (such as the UK’s Ordnance Survey’s coordinate system and the New Zealand map grid), and others cover states in the USA or parts of states. My goal for this column is to describe some of the major coordinate systems in use, explain how they can be used, and argue that they are suitable for standards-based, interdisciplinary, field-driven lessons.

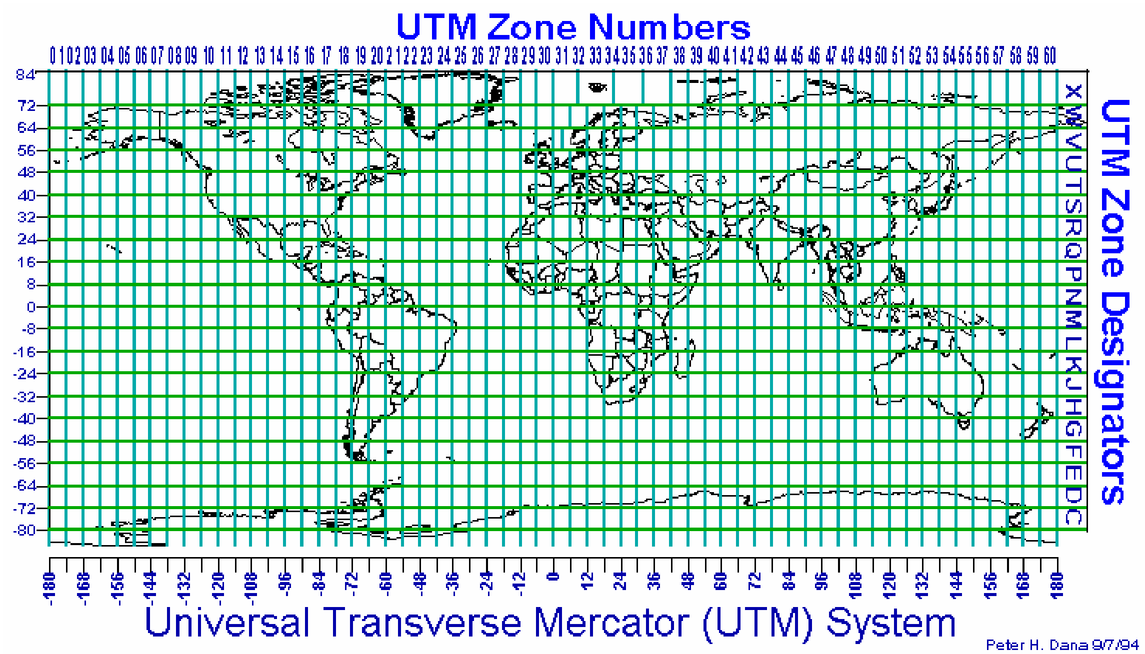
I have found that an effective way of introducing coordinate systems is to begin with the Cartesian coordinate system. Get out that graph paper! Talk about which quarter in the Cartesian coordinate systems are positive for x and which are negative for x, and repeat for y. Latitude and longitude, or the geographic coordinate system, is one most familiar to students and most often taught in schools. Latitude can be thought of as the lines that intersect the y-axis, and longitude as lines that intersect the x-axis. Just as the upper right quarter in the Cartesian coordinate system is positive for both x and y, it is positive for latitude and longitude. This represents most of Europe and Asia and some of Africa—the northern **and** eastern hemispheres. This will help students use GIS as well, as GIS coordinates are usually stored as positive numbers for the northern and eastern hemispheres, and negative numbers for the southern and western hemispheres. In addition, one could draw a cross section of the globe on the board and indicate that the angle between the equator and a line running “up” to the North Pole is 90 degrees, which is why the North Pole is 90 degrees north. Is your school closer to the equator or to the North Pole? What would be the halfway point?

In a strict sense, latitude and longitude is not really a coordinate system, because the grid does not have straight sides. However, it can be used as any other coordinate system to refer to the position of objects. One just needs to keep in mind that a degree of longitude is not constant over the Earth’s surface, but rather, decreases from 69 miles at the equator to zero at the poles. One effective way to illustrate this convergence is to show one USGS 1:24,000-scale map in the northern part of the USA, and one in the southern part. They both span 7.5 minutes of longitude, but the one in Minnesota will be narrower than one in Florida or Hawaii.

Three commonly used ways of displaying latitudes and longitudes exist, and they are all based on the idea of precision. To illustrate precision, let’s say I told Angela to meet me at 4pm in the cafeteria. If Angela shows up at 3:58pm and I appear at 4:02pm, it is not a problem—the time we agreed upon was understood to be approximate. Now, however, say that Angela is appointed Chief of NASA Johnson Space Center. She won't say "We'll launch the rocket at about 4pm." Rather, if she says 4pm, she means **exactly** 4:00:00pm, because many things need to happen at .01 seconds before the launch, .05 seconds before the launch, and so on. Therefore, for some things, we need more precision, and for others, we need less. Illustrate for your students what would happen if they rounded the coordinates of their school to the nearest latitude and longitude. Where is this point on the Earth's surface? It could be dozens of kilometers from the school.

One can use all three commonly used ways of displaying latitude and longitude to teach geographic and mathematical concepts. The first is degrees-minutes-seconds. For more precision, we divide each degree into 60 minutes and each minute into 60 seconds. I usually teach this base 60 concept using time—hours, minutes, seconds. A USGS 1:24,000-scale topographic map covers 7.5 minutes of latitude and 7.5 minutes of longitude. Have students compute the distance in minutes between the corners of the map to verify that the map truly covers 7.5 x 7.5 minutes. The second method of displaying latitude-longitude is decimal minutes, or fractions of a minute. Latitude 40 degrees 30 minutes 7 seconds north in degrees-minutes-seconds is the same as latitude 40 degrees 30.117 in decimal minutes. The third method is decimal degrees. This same latitude is (40 + 30/60 + 7/3600) = 40.502 in decimal degrees.

Another coordinate system is Universal Transverse Mercator (UTM). Using latitude-longitude is valuable because one can use the globe to introduce the concept, and because it is the first coordinate system that students learn. However, in latitude-longitude, it may be 7 seconds between one end of the school to the other, or (7/3600) = .0019 degrees. Seconds and fractions of degrees are both difficult distances to visualize. In contrast, UTM is valuable because its unit is the meter, a length that students already understand. UTM was created by the National Geospatial Intelligence Agency (NGA), formerly NIMA and before that, the Defense Mapping Agency. UTM covers most of the planet except for Polar Regions. In this system, the world is divided into 60 north-south zones, each 6 degrees wide.



As shown on this map, UTM zones are numbered consecutively beginning with Zone 1 from 180 degrees west to 174 degrees west longitude. In each zone, coordinates are measured as northings and eastings in meters.

NCGE headquarters in Alabama is in Zone 16 because it lies between 84 degrees west and 90 degrees west. The northing values are measured from zero at the equator in a northerly direction. In the southern hemisphere, the equator is assigned a false northing value of 10,000,000 meters. The central meridian in each zone is assigned an easting value of 500,000 meters. In Zone 16, the Central Meridian is 87 degrees west. One meter east of the central meridian is 500,001 meters easting. With a GPS or a topographic map, for example, one could ask students if the numbers increase or decrease as one walks north, east, south, or west. Because one could have UTM coordinates of 490,000 meters easting and 4,300,000 meters northing in California or, say, in Virginia, the correct zone must always be listed when giving UTM coordinates. UTM is especially effective with GPS because the student can clearly see the numbers changing by one meter each time a giant step is taken.

Another coordinate system is the state plane coordinate system. This system is actually a series of separate systems, each covering a state, or a part of a state, and is only used in the USA. It is popular with paper and digital map data from some state and local governments due to its high accuracy, achieved through the use of relatively small zones. State Plane began in 1933 with the North Carolina Coordinate System and in less than a year, it had been copied into all of the remaining states. The system is designed to have a maximum linear error of 1 in 10,000 and is four times as accurate as the UTM system.

Like the UTM system, the state plane system is based on zones. However, the 120 state plane zones generally follow county boundaries, except in Alaska. Given the state plane system's desired level of accuracy, larger states are divided into multiple zones, such as the “Colorado North Zone.” State plane zones whose long axis run north-to-

south (such as Idaho and Illinois) are mapped using a Transverse Mercator projection, while states whose long axis runs east-to-west (such as Washington and Pennsylvania) are mapped using a Lambert Conformal projection. In either case, the projection's central meridian is generally run down the approximate center of the zone.
A Cartesian coordinate system is created for each zone by establishing an origin some distance (usually 2,000,000 feet) to the west of the zone's central meridian and some distance to the south of the zone's southernmost point. This ensures that all coordinates within the zone will be positive. The X-axis running through this origin runs east-west, and the Y-axis runs north-south. Distances from the origin are generally measured in feet, but sometimes are in meters. X distances are typically called eastings (because they measure distances east of the origin) and Y distances are typically called northings (because they measure distances north of the origin).

Using coordinate systems are an effective preparation for using GPS. All GPS units can switch between dozens, if not hundreds, of coordinate systems. In addition, becoming familiar with these coordinate systems is excellent background for using GIS, because all spatial data used in a GIS is cast onto one of these coordinate systems. In addition, one can switch between different coordinate systems in a GIS.

All of these systems are valuable to teach and to learn. If time allows, get a map of a country outside the USA and examine the coordinate system in use there. In my next column, I will illustrate how to use topographic maps to use and teach about these three coordinate systems. What **do** all those little numbers in the margins of the maps mean? Look for the next column and find out!