Helping Educators Implement GIS in K-12 Education

Joseph J. Kerski, Ph.D.
Geographer
USGS
Box 25046 MS 507
Denver CO 780225-0046 USA
http://education.usgs.gov
Tel 001-303-202-4315
Fax 001-303-202-4137
My biography: http://home.earthlink.net/~jjkerski
Email: jjkerski@usgs.gov

Abstract

The plethora of spatial data sets, books, software, online tools, and training available to educators today presents a challenge for implementing Geographic Information Systems technology and methods in formal and informal education. This paper presents starting points for doing so throughout the educational curriculum, and begins with the heart of the matter—mapping for understanding our changing world.

Mapping For Understanding Our Changing World

People have always been fascinated with investigating their home—the Earth. For centuries, maps have stirred imaginations and inspired explorations of the unknown. Maps are a rich source of information, showing spatial relationships between climate, vegetation, population, landforms, river systems, land use, soils, natural hazards, and much more. Maps are excellent tools for investigating the "whys of where"—the essence of geographic and Earth Science inquiry.

However, as rich as paper maps are, they are limited in terms of investigating one of the fundamental tenets of Earth Science—the changing Earth. With the advent of today's geotechnologies, such as web mapping services and Geographic Information Systems (GIS), the teacher and student can analyze landscape change. These changes include those brought about by physical forces such as volcanic eruption, river meandering, and plate tectonics, as well as those brought about by human forces, such as urban growth. Increasingly, many changes are a combination of the two. Soil erosion, a natural process, can be exacerbated by human agricultural practices. Coastal erosion may be hastened by sea level rise and climate change brought about by human impact on the biosphere. River flooding may be more widespread due to the construction of artificial levees along the banks.

With the plethora of computer mapping technologies that exist today, it may be a challenge deciding which resources and tools are most valuable for the classroom. This article focuses on a few excellent places to start, and ideas on how to use these resources in the classroom.

And let's face it—nearly all issues and problems in our world, in our region, and in our community have a change component. Think of climate change, urban sprawl, crime, water quality, biodiversity loss, terrorism, and natural hazards, for starters. Change is at the heart of every one of them—whether measured over a few seconds, minutes, days, or millennia. We can use computer mapping tools and inquiry-based methods to investigate these in a standards-based educational environment—not only in Earth Science, but in geography, environmental studies, history, mathematics, chemistry, biology, and other disciplines. In addition, geotechnologies were named in 2004 by the US Department of Labor as one of three major growth fields for the 21st Century (along with nano- and bio-technologies)— as mapping services find their way into cell phones, handheld computers, and vehicles, you can open up this career path to your students!

Because the Earth is monitored as never before, satellite images and aerial photographs are often collected before, during, and after an Earth-changing event, such as a natural disaster. For example, hundreds of locations were photographed before and after Hurricane Katrina struck the Gulf Coast of the USA in August 2005. Digital Globe, other private satellites, the USGS Landsat satellite, and airplanes commissioned by government agencies and private companies all collected imagery. USGS before-and-after aerial photographs can be viewed at: http://coastal.er.usgs.gov/hurricanes/katrina/.

The pier, pier house, and antebellum house are clearly visible in the top image at Biloxi, Mississippi, taken in 1998. The bottom image shows the same location on 31 August 2005, two days after Hurricane Katrina made landfall. These types of images are incredibly powerful tools,

and can be effectively used with students to help them grasp the impact that hurricanes have on people and the environment. They can open a dialogue about natural hazards, public policy, and human-environment interaction. These issues can frame good geography and Earth Science inquiry.

Educators worldwide have been using the USGS topographic maps and digital aerial photographs on Terraserver (terraserver-usa.com) since it came online in 1998. They have been examining their school building and the surrounding neighborhood, the exact spot where the Mississippi River flows into the Gulf of Mexico, the San Andreas Fault, ancient glacial lakeshores in North Dakota, urbanization along the Colorado Front Range, the effects of the Public Land Survey System in Iowa, and much more. These images make excellent graphics to reinforce such lessons as glaciation, land use, population, and plate tectonics.

However, because the maps and images were compiled at different dates, they can also be used to teach landscape change. For example, examine the following aerial photographs from Terraserver for three different years for a school near the USGS office in Lakewood, Colorado.

The school in 1995 appeared as two concentric circles.

By 1999, construction at the school made part of the grounds appear quite bright. I also ask students to determine what time of day the photographs are flown. With north at the top of each image, they can see that the 1995 photograph was flown in the morning and the 1999 photograph in the afternoon. I also ask them whether they can determine whether it was a school day.

By 2002, construction was complete. The school had a new building, but was it completely new, or were parts of the old building retained? Also, what happened to the trees around the old parking lot?

Students can also compare the aerial photographs to a topographic map of the same area. Topographic maps are available digitally on the same Terraserver site, or on www.topozone.com.

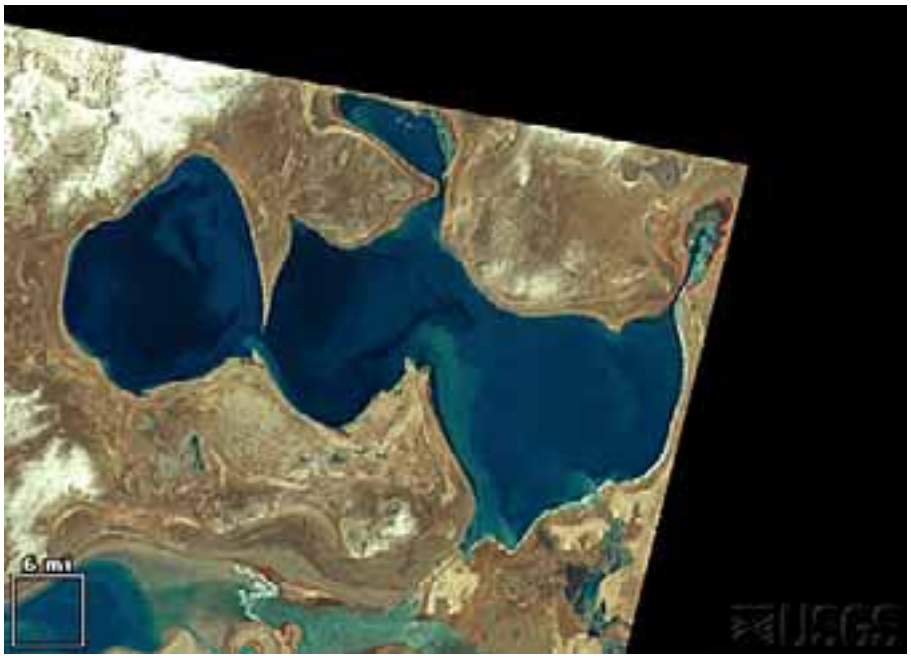
Paper maps can be purchased from the USGS, checked out from libraries, or bought from commercial map and sporting goods dealers. Topographic maps are typically older than the aerial photographs. Even older historical maps may be available. To obtain a historical topographic map, call 1-888-ASK USGS. For a minimal cost, you can obtain a black-and-white print of a historical topographic map. We also maintain an agreement with some USGS business partners who scan historical maps and can provide them in color, as digital files or prints.

In addition, some private companies and universities serve archives of historical topographic maps on the Internet. One such service from MapTech, on: http://historical.maptech.com/, offers historical topographic maps for free download for much of the terrain from Maine to Ohio. NOAA's Office of Coast Survey's Historical Map and Chart Collection contains over 20,000 maps and charts from the late 1700s to present day. The collection includes some of the nation's earliest nautical charts, hydrographic surveys, topographic surveys, geodetic surveys, city plans and Civil War battle maps, on: http://chartmaker.ncd.noaa.gov/csdl/ctp/abstract.htm.

The USGS topographic map of New Albany, from 1904, above left, compared to the 1995 map at right illustrates changes that could be examined in every community. Using historical and current maps and imagery, students could answer such questions as the following: What has changed, and why has it changed? Was it because of natural forces or human-caused forces? What do you predict this area will look like when you graduate from secondary school? From university? In 50 years? What did the landscape look like when your parents were students? When your grandparents were students? What did it look like 100 years ago? Is the area changing more quickly or more slowly than other parts of your community, or other parts of the country or world? Why? What is the land use like in your neighborhood? How does it compare to land use elsewhere in the United States? What influence does population, climate, proximity to coastlines, and other phenomena have on land use? Can you estimate the population in the map or photograph of the area? What type of dwellings do people live in around the area? How do these compare in size and density to other parts of your city? How much terrain is visible at a resolution of 1, versus 2, 8, or 16 meters? How does detail change as the scale changes? What is the best scale to view a glacier? A school building? A city? Examine some aerial photographs taken in summer versus winter, spring, and fall. What are the differences in terms of vegetation and sun angle?

In a similar fashion, educators can take advantage of historical satellite images on earthshots.usgs.gov. Because the USGS and NASA have been operating the Landsat satellites since 1972, we have nearly a 35-year documentary of the Earth's surface. Use Earthshots, a

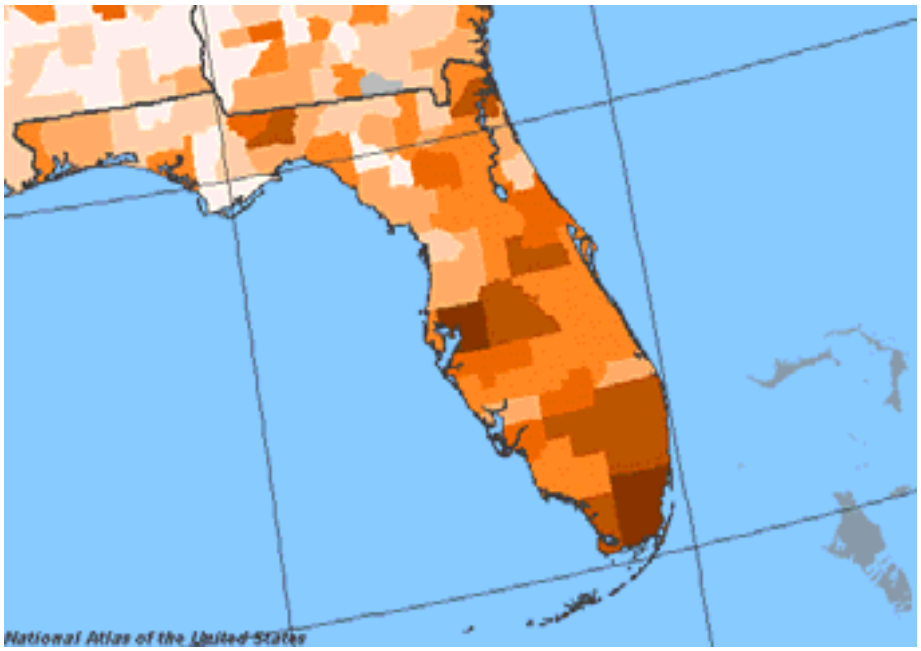
collection of images for selected regions of the Earth that have experienced rapid change, to investigate the reasons for those changes.

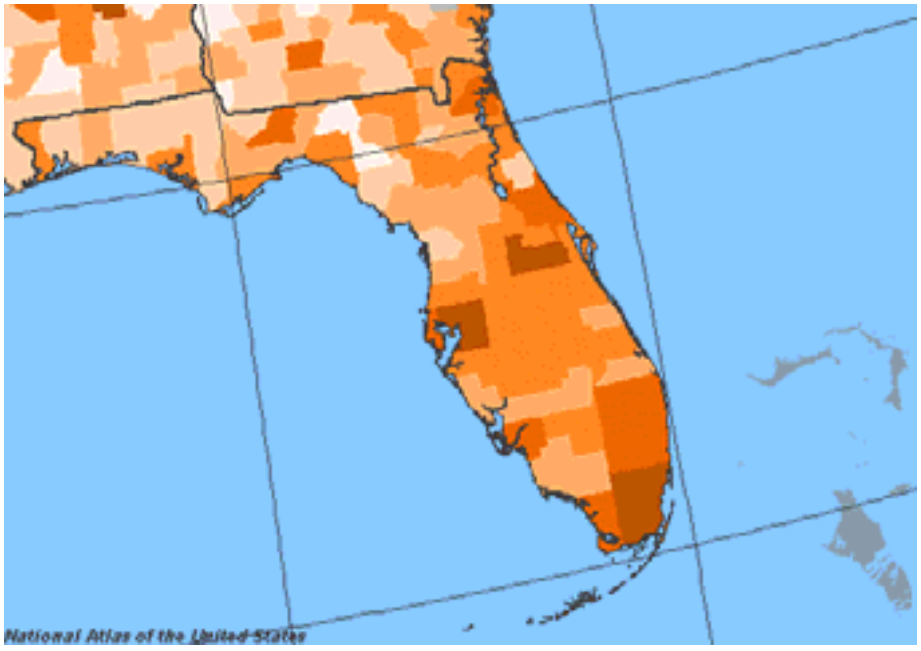


For example, the complex issue of irrigation, politics, climate, and internal drainage can be discussed with illustrations from the Aral Sea as it shrank from 1973 (above) and 1999 (below).

The National Atlas (nationalatlas.gov) is another excellent educational resource, a collaborative effort among over 20 federal government agencies, including the USGS. It enables the teacher and student to create easy-to-use maps of America's natural and cultural landscapes, and illustrate how they change. Selecting “Map Maker” on the National Atlas web site allows one to create maps according to nearly 200 themes, including agriculture, biology, boundaries, climate, environment,

geology, history, people, and transportation. Many of these themes have a time component, allowing for the comparison of change over time. For example, the West Nile Virus, 1980 to 2000 ethnicity and density of population, and seasonal greenness changes can be examined over time. For example, an examination of motor vehicle thefts from 1994 to 2002 shows that while parts of south and central Florida experienced a decrease, many rural counties, especially in southern Alabama, saw an increase.





Use the National Atlas to understand complex relationships between environments, places, and people. Students can use the atlas with guiding questions from their instructor to understand the environmental, resource, demographic, economic, social, political, and historical dimensions of American life. Other maps point to different sets of questions. How do landforms, geology, and climate affect the distribution of human population in the United States? What are the fastest

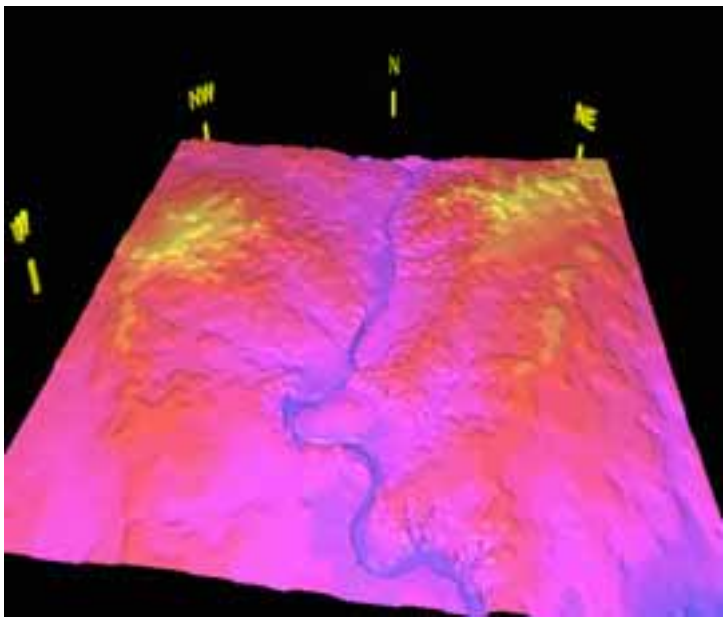
growing regions of the United States in terms of population? Is your area growing rapidly, slowly, or not at all? Why? What is the relationship between certain types of crime in different regions to the total population that lives in the area? To the age of the population there? Why? Maps at the National Atlas can help your students answer all these questions and, more importantly, see and understand the patterns that like beneath the answers.

As excellent as these resources are, others do exist. It does not matter so much which resources are used to examine the changing Earth. The most important thing is that images and maps are used repeatedly to examine our dynamic planet. Students can use them to understand that the Earth **is** changing and begin to think scientifically and analytically about **why** it is changing. They can then ask, **should** it be changing in these ways, and is there anything we can and should do about it? This captures the heart of scientific thinking, spatial analysis, and inquiry in action.

Resources for GIS in K-12 Education

How educators begin using GIS in K-12 Education? Begin with the above framework of why place and space matter. Then begin to investigate resources as follows.

Geographic information systems (GIS) provide a technology and method to analyze spatial data, or information about the Earth. The earth's climate, natural hazards, population, geology, vegetation, soils, land use, and other characteristics can be analyzed in a GIS using computerized maps,



aerial photographs, satellite images, databases, and graphs. By analyzing phenomena about the Earth's hydrosphere, lithosphere, atmosphere, and biosphere, a GIS helps people understand patterns, linkages, and trends about our planet.

The USGS has been producing digital map data since the 1970s. These data sets include scanned topographic maps, digital aerial photographs, land use and land cover, hydrography, transportation, 3D models of the Earth's surface, satellite imagery, and more. The USGS makes extensive use of GIS to analyze urban growth, investigate the downstream effects of abandoned mine lands, to create flood models, and in other research.

Since the 1960s, GIS has quietly transformed decision-making in universities, government, and industry by bringing digital spatial data sets and geographic analysis to desktop computers. Geographic Information Sciences include Geographic Information Systems as well as the disciplines of geography (examining the patterns of the Earth's people and physical environment), cartography (mapmaking), geodesy (the science of measuring and surveying the Earth), and remote sensing (studying the Earth from space).

GIS is used in three major ways in courses at the elementary, secondary, and university level. First, teaching about GIS dominates at the community college and university level, where courses in methods and theory of GIS are taught in geography, engineering, business, environmental studies, geology, and in other disciplines. Second, teaching with GIS is emphasized at the elementary and secondary level, where GIS is used to teach concepts and skills in earth science, geography, chemistry, biological science, history, and mathematics courses. Finally, GIS is used as an essential research tool in all institutes of higher education in geography, demography, geology, and other disciplines.

The U.S. Labor Secretary's Commission on Achieving Necessary Skills (SCANS) stated that the most effective way to teach skills is "in context" (U.S. Dept. of Labor 1991). SCANS competencies include identifying resources, working with others, using information, and understanding complex and changing inter relationships. Implementing GIS into the curriculum may encourage students to examine data from a variety of fields.

In 2004, the US Secretary of Labor named geotechnologies as one of the three fields most in

demand for 21st Century decision-making. In 2005, the US Department of Labor began funding community college and other programs to improve the number and breadth of GIS courses and resources offered.

Since the publication of the first national content standards in geography (Geography Education Standards Project 1994), social studies (National Council for the Social Studies, National Task Force for Social Studies Standards 1994), science (National Research Council 1996), and technology (International Society for Technology in Education 2000), educators nationwide have been progressing toward a model of instruction that emphasizes a hands-on, interdisciplinary, research-based learning experience. The national geography standards state, “the power of a GIS is that it allows us to ask questions of data.” Students using this inquiry approach form research questions, develop a methodology, gather and analyze data, and draw conclusions.

The National Academy of Sciences report *Learning to Think Spatially—GIS Across the Curriculum* (2006) emphasized the value of spatial thinking in geography and other disciplines, and needs to be cultivated throughout the curriculum.

The problems we face in the 21st Century—natural hazards, crime, terrorism, water availability and quality, biodiversity loss, climate change, urban sprawl, energy needs, and many more—are becoming more serious and are growing in geographic extent, affecting individuals’ everyday lives. Each of these problems has a geographic component. Education in spatial analysis using GIS as the tool is the important skill that must be promoted if we hope to grapple with these issues.

The approach with GIS should not be, "How can we get GIS into the curriculum?" but "How can GIS help meet curricular goals?"

Examples of GIS In Education

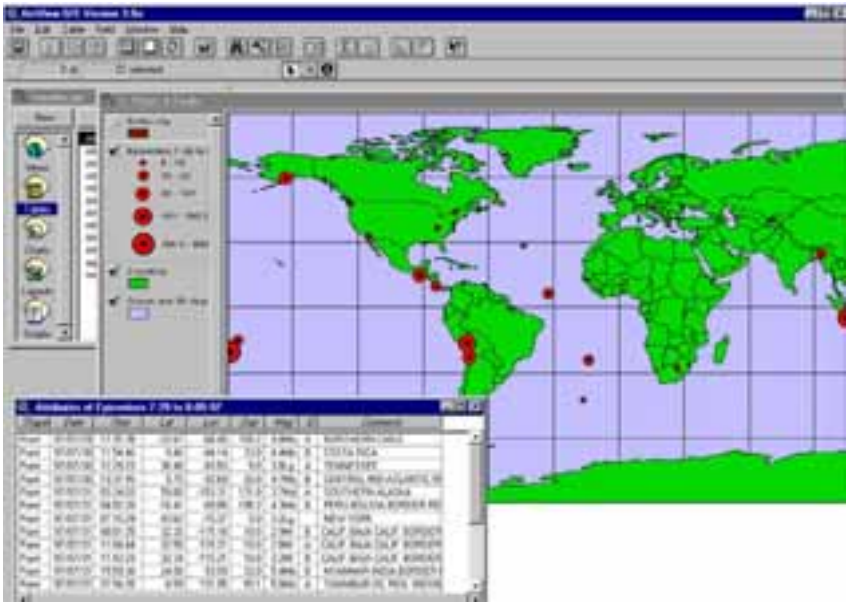
Students using GIS in the curriculum are studying phenomena from the local to global scale. The use of GIS fosters a connection with the community through the acquisition of data and maps and through field work.

With GIS, students can examine the Earth in a new way, through three-dimensional analysis of a watershed, or by examining the Pacific “Ring of Fire” using a map projection that shows all of the Pacific Ocean in one view.

Vermont middle school students use GIS technology, science journals, and photographs to determine the origin and ecological relationship of a local pond to the community.

Idaho students use GIS to examine the history of mining and cemeteries in their community.

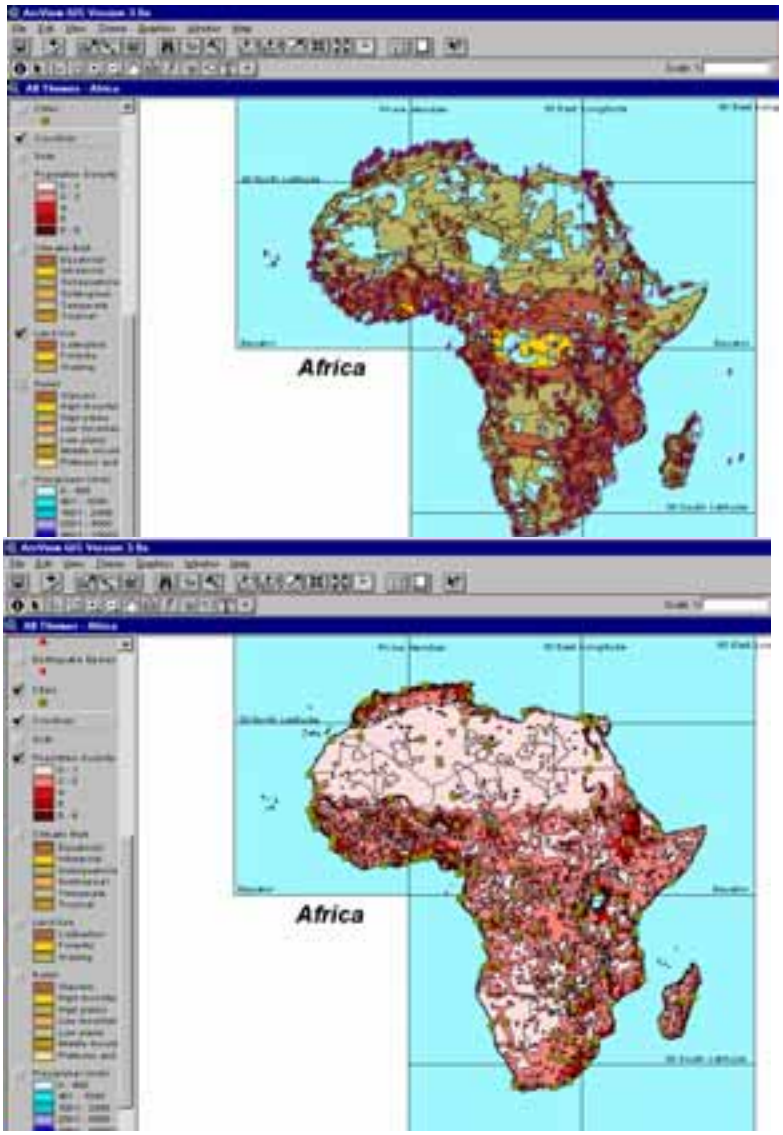
Rhode Island students study the economic impact of rivers in their communities. Other students map and analyze tree species on their school property.



In science courses, students use USGS earthquake information on the Internet in a lesson on plate tectonics (below).

In North Dakota, high school students help state parks use GIS to study and manage their resources. Middle school students map alternative sites for a local landfill.

World Geography students examine the climate, vegetation, population, natural hazards, landforms, and political geography of Africa (below).



Students use GIS with Global Positioning System (GPS) receivers to collect coordinates and chemical constituents of local streams, such as pH, dissolved oxygen, and conductivity (below).

North Carolina students use GIS to study the history and development of the African American community in their city. Students in Los Angeles map and analyze the ethnic makeup of neighborhoods over time.

Get started with GIS and spatial analysis in your curriculum! The following are excellent starting points for data, software, books, and training.

Starting Points

GIS in Education:
education.usgs.gov

USGS online aerial photographs and topographic maps:
terraserver-usa.com

Educational Applications of GIS:
www.esri.com/k-12

National Atlas
nationalatlas.gov

Geography Network
www.geographynetwork.com

Software

ArcView
ArcGIS
ArcExplorer Java Edition for Education

by Environmental Systems Research Institute (ESRI): ***http://www.esri.com***

Events

GIS Day:
www.gisday.com

ESRI hosts an international conference in GIS education each summer in California: www.esri.com/educ

Listserv

TERC's EDGIS listserv, a discussion forum about the implementation of GIS in the curriculum: list.terc.edu/mailman/listinfo/edgis

Books and Lessons

Mapping Our World: GIS Lessons for Educators and Community Geography: GIS In Action, both from ESRI Press

ArcLessons:
www.esri.com/arclessons

List of Training Events:
kangis.org/learn

References

Geography Education Standards Project. 1994. Geography for Life: National Geography Standards. Washington, DC: National Geographic Society, 272 p.

International Society for Technology in Education. 2000. National Education Technology Standards for Students. Eugene, Oregon: ISTE, 373 p.

National Academy of Sciences. 2006. Learning to Think Spatially—GIS as a Support System in the K-12 Curriculum. Washington DC: The National Academies Press, 313 p.

National Council for the Social Studies. 1994. Curriculum Standards for Social Studies. Washington, DC: NCSS, 178 p.

National Research Council. 1996. National Science Education Standards. Washington, DC: National Academy Press, 262 p.

U. S. Dept. of Labor. 1991. Secretary's Commission on Achieving Necessary Skills (SCANS). Washington, DC: GPO.

◆