

## Spatial Inquiry Using Web-Mapping Tools

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### GIS In Education

For 40 years, Geographic Information Systems (GIS) has quietly transformed how decisions are made in universities, government, and industry by bringing digital spatial data sets and geographic analysis to the computer environment. Not long after GIS began, the GIS community realized that a massive training effort was needed to equip people with the skills needed to effectively use GIS software and how to model the world within a GIS. Teaching *about* GIS had begun, and by the 1990s had expanded to include the breadth of what had become Geographic Information Science (GISc). Teaching about GIS provides a theoretical and practical foundation for careers in geographic information sciences, including such topics as database design and practical problem solving. By 2007, GIS courses, degree programs, and certificates were available at nearly every major university around the world, at many technical colleges, and in hundreds of online programs. They are taken by over 100,000 students annually (Phoenix, 2004), studying a broad array of disciplines including environmental studies, business, geography, Geographic Information Sciences, biology, engineering, Earth Science, and more.

Teaching *about* GIS dominates in higher education, although GIS courses are increasingly appearing at the secondary level and in nonformal educational programs. In 2004, the US Secretary of Labor named geotechnologies as one of the three fields most in demand for 21<sup>st</sup> Century decision-making. At the same time, the general public is becoming more spatially aware with the advent of digital maps for directions, travel, and exploration on their computer, cell phone, PDA, and in their vehicles. Operating behind the scenes is an increasing awareness of the interconnection of people and the planet, coupled with increasing and jarring reminders that the pervasive problems of our world need a holistic and geographic approach to solving them. The spatial patterns evident in Figure 1 are much more difficult to discern with tabular data or with charts alone, showing the GIS advantage:

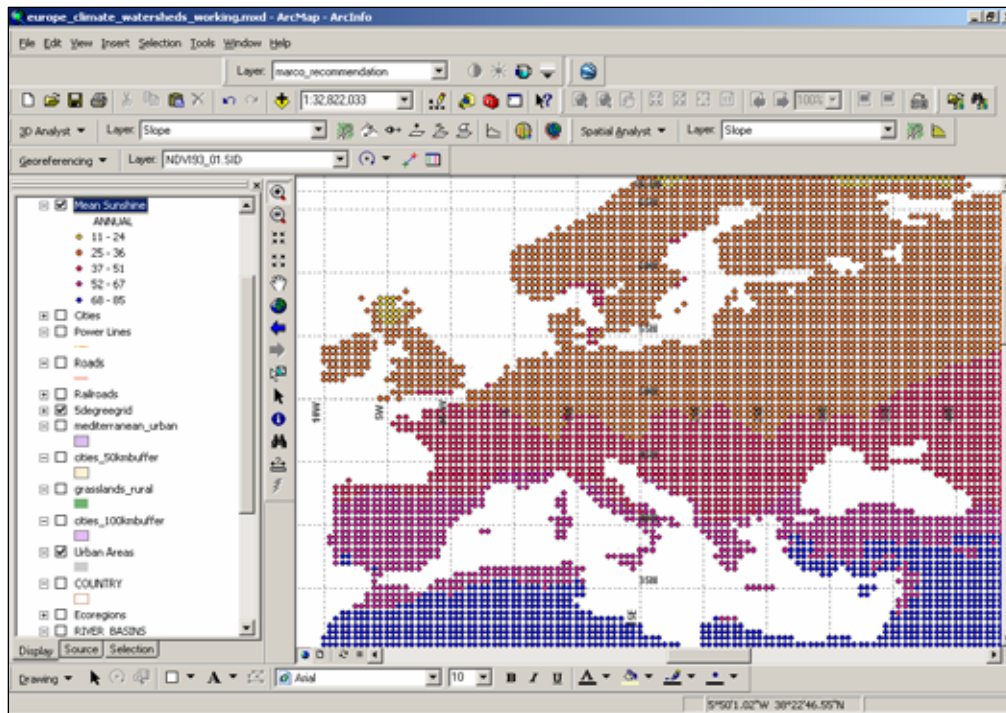


Figure 1. Climate analysis for Europe and surrounding regions, showing mean annual sunshine, in percent, with the highest values in blue and the lowest in red. Here, sunshine data is stored as point data spaced evenly each half-degree of latitude and longitude.

As GIS became easier and more practical to use, educators began to use it in other disciplines, such as biology, geography, chemistry, history, mathematics, and even language arts. By the early 1990s, teaching *with* GIS had begun. Teaching *with* GIS represents the second way that GIS is used in education. It began at the primary and secondary level from educators who wanted to help their students learn about plate tectonics, biomes, climate, economics, migration, history, population, and other topics and issues, but has also been spreading across departments at the university level and on university campuses (after Sui, 1995).

The third way that GIS is used in education is as a research tool, in departments of geography, education, demography, geology, and in other departments and disciplines in higher education. GIS is useful anytime the “where” question is asked in a research problem. The fourth way in which GIS is used in education is as an administrative tool to manage campus infrastructure, including security, buildings, telecommunications, enrollment, recruiting, and the alumni network.

Driving these efforts is an emphasis in educational standards worldwide on using real-world data and methods to solve real-world problems. GIS relies on and fosters a mindset of exploration—it is the GIS user that makes the decisions, not the software. The student has to think about what he or she is displaying or

modeling on the screen—no button or menu will solve that problem for them. GIS promotes finding information and knowing what to do with it. Geotechnologies provide instruments for implementing geographic thinking by employing the geographic inquiry process:

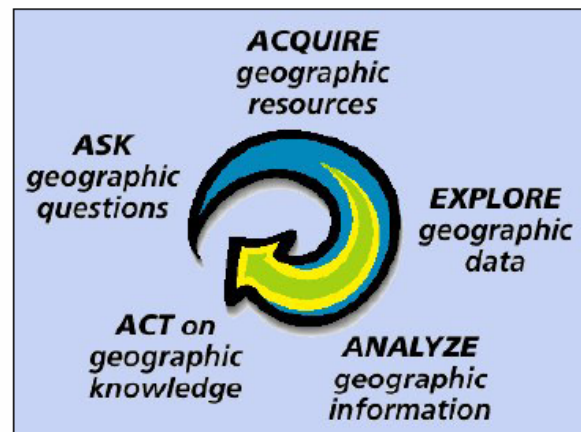


Figure 2. The geographic inquiry process.

The geographic inquiry process often leads to a new question or multiple questions. GIS is a perfect tool to analyze the “what if...” questions. GIS allows for both context and content to be analyzed—both location (where is it?) and place (what is it like?). The characteristics of place, whether they are watersheds, communities, neighborhoods, or entire ecosystems, can be analyzed in the context in which they occur on the Earth’s surface, through modeling the complexities of the real world.

Some educators in many parts of the world have been progressing toward a model of instruction that emphasizes a hands-on, interdisciplinary, research-based learning experience. The US 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. Teaching with GIS allows for authentic tasks and assessments, and problem-based, team-based learning. Teaching with GIS is one practical way to use constructivism to help students understand their world. In a GIS, just as in lifelong learning, the process is even more important than the product. Many educators have found that the use of analytical tools such as GIS helps nudge students toward the top of the pyramid envisioned in Bloom’s taxonomy:

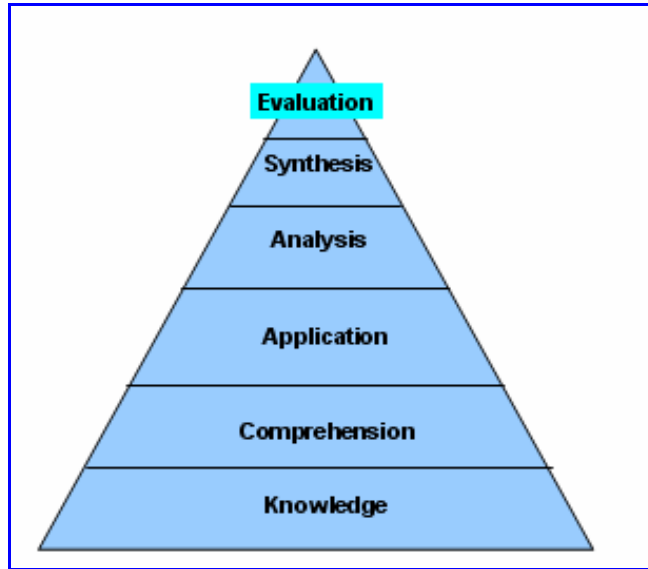


Figure 3. Bloom's Taxonomy (1956) of six levels within the cognitive domain, from the simple recall or recognition of facts, as the lowest level, through increasingly more complex and abstract mental levels.

Another driving force behind using GIS in education has been the U.S. Labor Secretary's Commission on Achieving Necessary Skills (SCANS) report, stating 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. 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. Geotechnologies do not take place only in the computer lab—fieldwork is an important component. The importance of equipping students with field experiences while they are young and as frequently as possible has been well documented, perhaps most eloquently by Louv (2005) in *Last Child in the Woods*.



Figure 4. Collecting chemical constituent samples from the Pacific Ocean and GPS coordinates as part of the Maui Digital Bus program resulting from multiple partnerships.

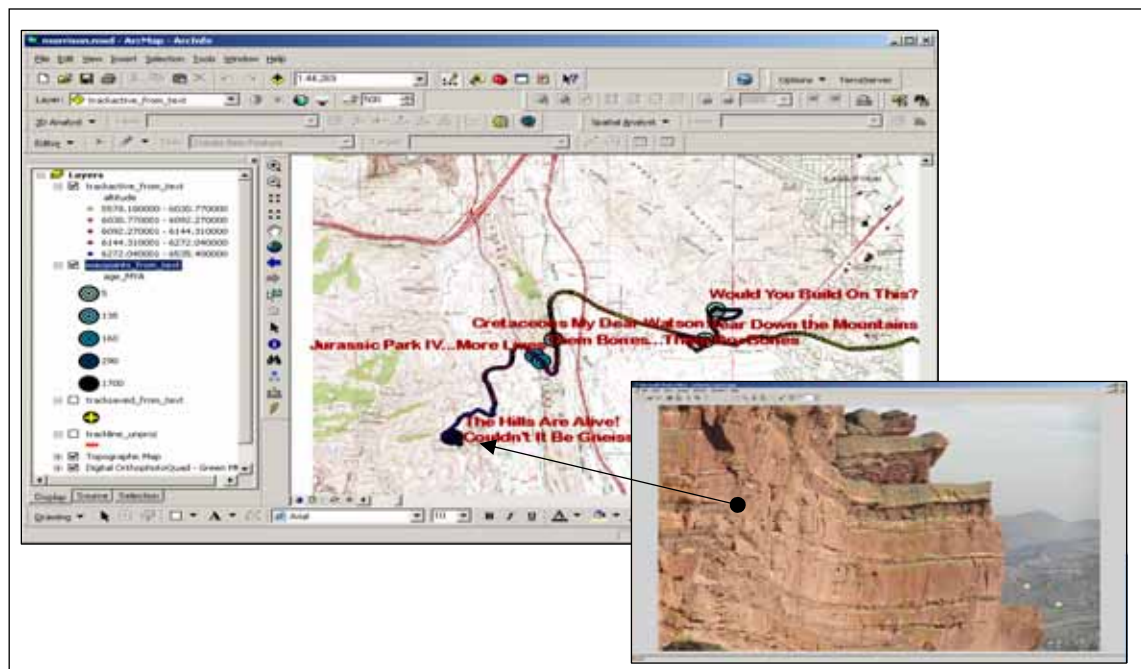


Figure 5. Ground photograph hyperlinked to geologic field data and GPS coordinates that have been uploaded into the GIS environment.

### Examples of Teaching With GIS

Examples of students using GIS in the curriculum to study phenomena from the local to global scale abound. Many examples show that using GIS together with GPS and Remote Sensing fosters a connection with the community through the acquisition of data and maps and through fieldwork. Using GIS, students have

examined the Earth through three-dimensional analysis of a watershed, and by examining the Pacific “Ring of Fire” using a map projection that shows all of the Pacific Ocean at once. Other students mapped animals struck by vehicles on a mountain pass and planned the location for a parking lot that would least impact a local wetland. Still others mapped human-set fires understand the geography of Africa. Some students began to understand the pattern and causes of teen driving accidents in their local community using GIS. Others compiled a spatial database of trees by height, species, and condition on their school property that was adopted by their town council for the town’s tree database. North Carolina students use GIS to investigate 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.

These developments are not confined to the USA. Students in Denmark investigate the reason for the location of wind farms and suggest additional suitable sites. Canadian Middle school students map alternative sites for a local landfill. New Zealand students investigate the distribution of gorse in their region and its relationship to the occurrence to wildfires. Costa Rican students mapped Nicaraguan refugees in their own region to understand how to help them and how to advocate their government to provide services to them.

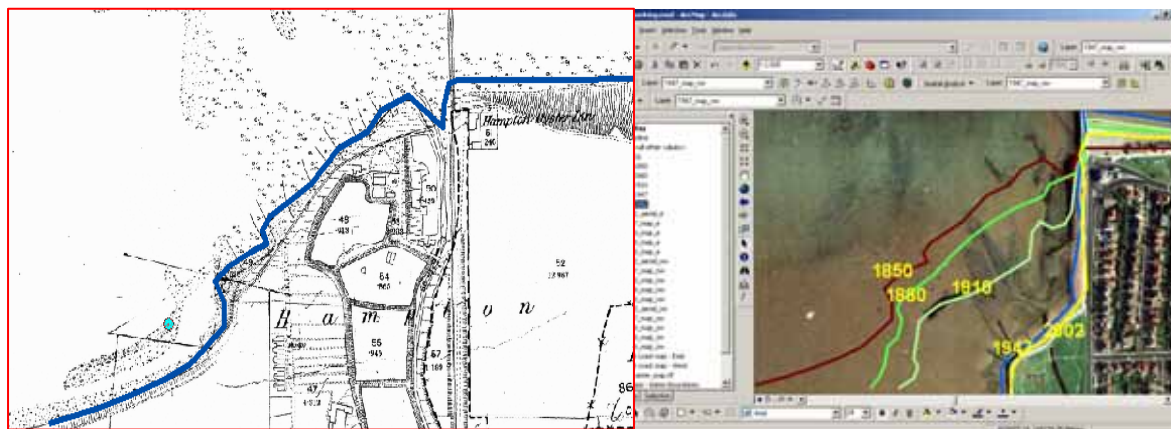


Figure 6. Students in the UK learn about coastal erosion in Kent, in southeast England, by drawing the coastline retreat using maps dating back to 1850 and current aerial imagery.

## Teaching With Internet-Based GIS in Education

Despite the changes in GIS in education over the past 20 years, its model of delivery has held remarkably constant over much of that time. While it is true that more spatial data has become available and accessible, and while hardware, software, and computer networks certainly became more powerful and mobile throughout the period, the hardware-software model of GIS use was much the same. This model consisted of loading and running GIS as a desktop software application on a computer running the Unix, Windows, or Macintosh operating system, and loading and using spatial data from an outside source. At first, the

source of this spatial data was from physical media—magnetic tapes, ZIP drives, CD-ROMs, DVDs, or some other external device, and later became increasingly downloaded from the Internet. However, the result was still the same—the data was stored on a hard disk. The hard disk was either local, externally attached to a local computer, or on a local network.

The above model provided the foundation for 20 years of teaching *with* GIS and *about* GIS (from Sui, 1995). However, since the advent of Internet-based GIS, teaching with GIS and teaching about GIS have both been slowly but inexorably changing. This chapter focuses on the changes that Internet-based GIS brings to teaching *with* GIS. These changes include opportunities as well as challenges.

These new tools present new opportunities for the educator as well as new challenges. As never before, educators have a wealth of geospatial tools at their fingertips, most of which require fewer hours of training than traditional GIS. These tools may hasten the ability of educators to meet spatial learning challenges as identified in the National Research Council's *Learning to Think Spatially* report (2005). They can support standards-based inquiry-driven methods of teaching and learning, while providing basic analysis tools for exploring geographic or scientific data (Baker, 2005). Challenges in using Internet-based GIS in education include data quality, functionality, computer security, Internet bandwidth, and distractions due to the visual appeal of these new tools. These tools can be used in a variety of ways such as in teaching about population characteristics, migration, economics, and history. They can be used at any scale—from analyzing locally collected data in the field to global issues and problems. In each application in education, students can learn about the processes that are active on our planet, and the reasons why those processes exist.

## **Benefits and Challenges of Internet GIS in the Curriculum**

### *Benefits to Internet-Based GIS in Education*

The advantages of Internet-based GIS for the educator are numerous (Baker, 2005). No software is required beyond a standard web browser. This alone, for instructors who are faced with difficulties with the school technology staff in installing any software not viewed as standard in the school, is a significant benefit. Furthermore, most web-based GIS require little time to learn, drastically reducing the time it takes for educators to incorporate them into their curricula. Dynamic content, such as real-time wildfires or earthquakes, can be analyzed online in a way not possible in the desktop environment. A significant advantage of online GIS over desktop GIS particularly in countries where all data are licensed is that the data are being viewed online and therefore is accessible without cost or licensing restrictions.

Many web-based GIS tools can be effectively used to enhance teaching and learning in conjunction with traditional desktop-based GIS. Teachers seem better able to make the leap to using maps to *analyze data* rather than just *look at places* when there is an intermediate technology that introduces them to spatial analysis. Most

of these tools function in the same way within a desktop GIS environment that they do in the Internet-based environment. Furthermore, Internet-based GIS provides an excellent avenue to more advanced spatial analysis with desktop GIS.

### *Challenges to Web-Based GIS in Education*

Challenges to the use of web-based GIS as an instructional tool exist just as they do in the desktop GIS environment. Most of these challenges are not easily solved with software and hardware, because they are embedded in the educational system itself (Kerski 2003). Digital maps, whether on the Internet or as part of a desktop GIS package, present special challenges for interpretation and analysis (Cammack, 1999). For teachers who have previously relied on maps only for reference, and not for investigation, this represents an interpretation as well as a pedagogical shift. Another challenge is that Internet-based GIS services do not and may never contain all of the functions available in a desktop GIS. A recurring theme of teaching with online or desktop GIS is data quality. Maps are by definition only representations of reality. With Internet-based GIS, much less of the data adheres to metadata standards, and therefore, varies more widely in terms of data quality. A further challenge of web mapping services compared to desktop GIS is that because the maps and services are online, one cannot teach with them if the website or the Internet connection is down. A related disadvantage for Internet-based GIS use is that, unlike desktop GIS use, it is difficult to save one's work and return it during the next day's class period. As web-based mapping tools have increased in power, many of them require a high-speed Internet connection, which although are becoming more common in primary and secondary schools, are far from ubiquitous.

Another challenge is that some of these services link to advertisements and chat rooms that either cause the entire site to be blocked by school servers or else are considered undesirable by teachers and school information technology staff. Internet-based GIS are often less stable than desktop GIS, and they are often slower, since they are streaming data over the Internet rather than simply showing data on the local computer. Some web-based services become so captivating to many students that they have a difficult time concentrating on the problems assigned. A related concern is how much "control" an instructor feels is necessary for successful teaching. For many educators, using the Internet for anything besides research for term papers is venturing into uncomfortable instructional territory.

### *An Example of Teaching With Internet-GIS in the Curriculum*

ArcWeb Explorer (<http://arcwebservices.com/awx>) is a web mapping service built by ESRI that effectively illustrates the power of some of these new tools. ArcWeb Explorer was built to showcase the data available through ArcWeb Services, a library of information and tools compiled by ESRI that contains over 100 different sources of spatial content such as streets, imagery, and even live data such as traffic. ArcWeb Services are a collection of tools that enables users to integrate



mapping, routing, and geographic reporting into their web sites, wireless devices, or desktop applications. With ArcWeb Services, neither the content nor the software has to be resident on a student or teacher's local computers. ArcWeb Services lets users perform a variety of spatial query and proximity searches on a host of datasets provided by some of the GIS industry's leading data providers or by other GIS users. With the routes, base maps, thematic maps, and reports, the goal in industry or in education is to solve geographic problems.

Students can use ArcWeb Explorer to investigate over 100 demographic variables down to the neighborhood level, such as total population, median income, education, age, and ethnicity. They can compare urban core neighborhoods to first ring suburbs to exurban to rural, or compare their own neighborhood to those nearby or across town.

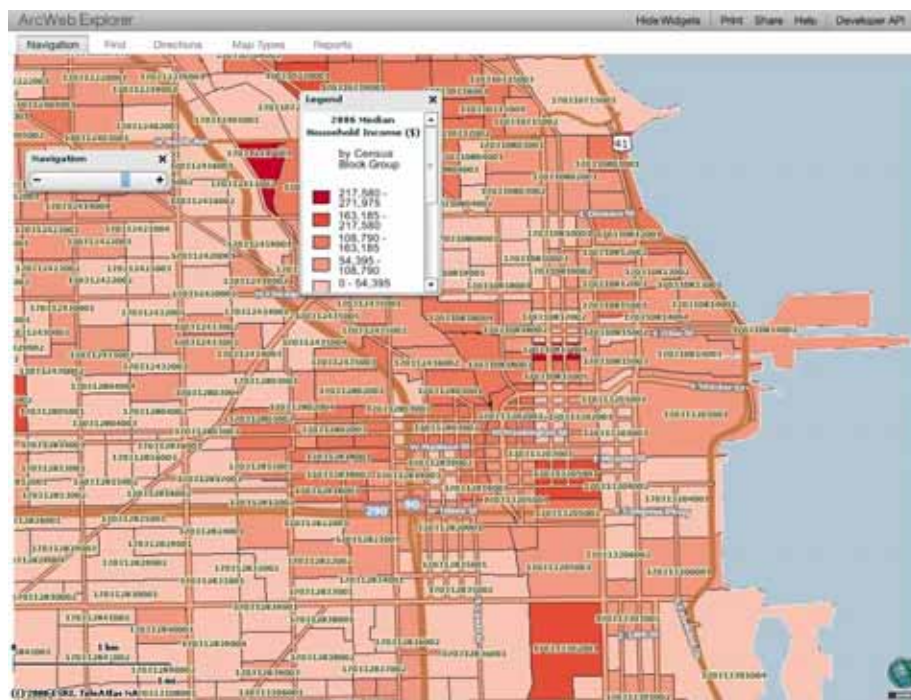


Figure 7. Map of median income in central Chicago created with ArcWeb Explorer, an online GIS service.

A map of median income in Chicago was produced through just three steps: First, Chicago was selected under the "find" tool, and zoomed to the desired scale. Second, Data Map Types was selected. Third, median household income was chosen for the variable. This map required less than one minute to build from the time the tool was first invoked, and no software was required other than a web browser. Therefore, students can quickly generate maps like this and quickly move to the level of geographic inquiry and analysis. This ability is one of the main advantages for educators who seek to nudge students beyond *reading* maps to *understanding* maps, but more importantly, to understanding their community, region, country, and world. Through this tool, students can think about the

*processes* behind the *patterns*, and investigate the *linkages and interconnectedness* of major geographic themes, such as scale, migration, climate, landforms, vegetation, land use, resources, energy, and more. They can tackle questions that go far beyond “Describe the pattern that you see” to “Why do incomes vary across neighborhoods?”, “Why are incomes high just outside of downtown, but decrease farther away from downtown?”, and “What will happen to these neighborhoods’ income levels in the future?” The advantage of Internet-based GIS allows students to more quickly get to the heart of geographic inquiry—asking the “whys of where” questions.

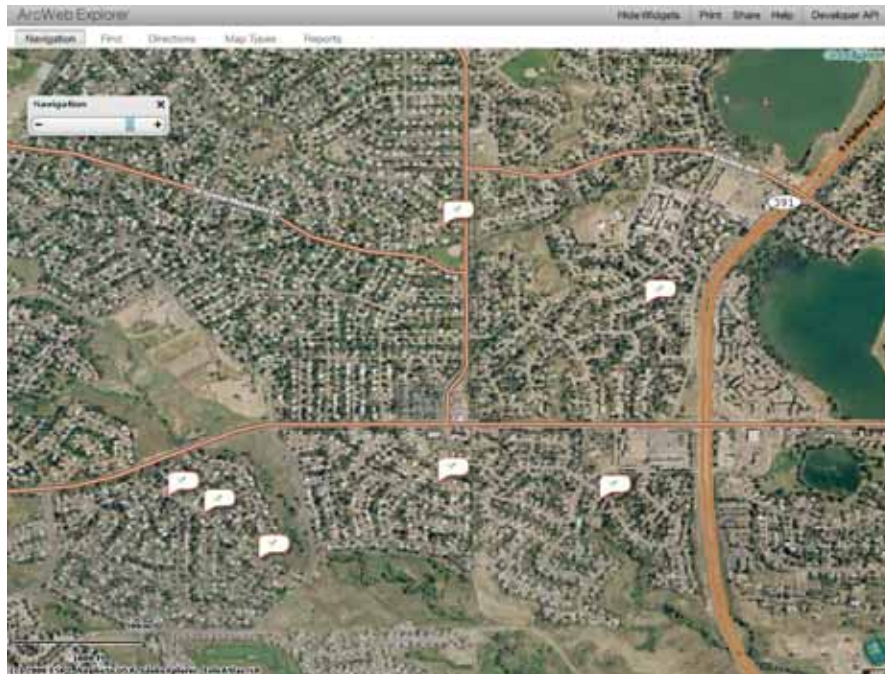


Figure 8. Map of student telephone numbers surrounding a school in Colorado, made with a spreadsheet and ArcWeb Explorer.

The same tool—ArcWeb Explorer—can be used to map the students’ own data. To map student phone numbers, a student created a two-column spreadsheet, and began with a row indicating the column names. The student entered the column names “name” and “phone.” The student then entered the names of friends and saved the spreadsheet on the local computer. Next, inside ArcWeb Explorer, instead of finding an address, a latitude-longitude location, a computer, or a URL, the student requested the service to find an Excel spreadsheet. The student pointed the service to the spreadsheet containing the phone number listing and the service mapped them in their correct geographic locations atop a hybrid street-satellite image map. The student could then analyze the diffusion of these phone numbers, clustered on the school that they all attend, visible in the west central section of the map. They could then compare the diffusion of students that attend a neighborhood school versus the diffusion of students who attend a magnet school that attracts students from a wide variety of neighborhoods across an entire

metropolitan area. They could then compare the size of these “student catchment basins” for a secondary school versus a community college, a regional university, and a national and international university. They could then think about the catchment basin for schools versus businesses, and examine why gas stations have a smaller catchment area than hospitals.

The ability to map one’s own data is certainly not commonplace in web mapping services, but is moving in that direction. Teachers can take advantage of these developments by having students map their field-collected latitude-longitude data with GPS receivers. They could also use online telephone directories, select certain businesses, and map them. Why do rental car companies cluster near airports, while others, such as check-cashing services, seem more scattered? These are questions that foster spatial thinking—students begin to understand that there is a reason for the location of just about everything.

### **Internet-Based GIS Services**

Online GIS services are produced by universities, local, regional, national, and international government agencies, nonprofit organizations, professional societies, and private companies. They are changing rapidly, are incredibly varied in their scale, coverage, themes, and purpose, and are therefore difficult to classify. Nevertheless, the resources below have been successfully tested in a variety of classrooms by the author and seem to fit logically into these categories.

#### *Mapping People at Places*

One category of Internet-based GIS services might be aptly entitled “Mapping People at Places,” and include services that allows for customized thematic mapping of variables. American FactFinder provides for demographic and housing variables by neighborhood from the 2000 U.S. Census of Population and Housing (<http://factfinder.census.gov>). Social Explorer, from Queens College of the City University of New York (<http://socialexplorer.com>) allows for the analysis of detailed historical U.S. Census maps and reports back to 1940. The Modern Language Association’s web mapping tool allows languages spoken in the USA to be analyzed by state and by country ([http://www.mla.org/census\\_map](http://www.mla.org/census_map)). Cartograms, maps that convert areas into sizes based on numeric variables while maintaining some degree of geographic accuracy, can be explored by country using World Mapper (<http://www.worldmapper.org>). National Geographic’s MapMachine allows for mapping population density, ecoregions, satellite imagery, climate, and other variables for the globe (<http://nationalgeographic.com/maps>). NationMaster provides a wealth of raw and ranked statistics by country displayed as tables and graphs (<http://www.nationmaster.com>), allowing for import into a GIS package, and by state (<http://www.statemaster.com>).

#### *Mapping Your Own Places*

Another category of Internet GIS services could be named “Mapping Your Own Places” because these allow for dynamic maps to be combined with the user’s own data. GPS Visualizer (<http://gpsvisualizer.com>) allows for the user’s latitude-longitude coordinates from a GPS to be mapped atop a satellite image. An increasing number of services allow for the tagging of photographs to an online map or satellite image, such as Wayfaring (<http://www.wayfaring.com/>) Flickr (<http://www.flickr.com>), you’re YourGMap (<http://yourgmap.com>). A different kind of service built specifically for education maps student responses to online surveys (<http://kangis.org/mapping/sdm/>). The surveys can be of the student’s own or the teacher’s own creations.

### *Mapping Real-Time and Near-Real-Time Data*

A variety of mapping services bring in real-time and near-real-time data to students for analysis. Examples include examining the pattern of wildfire perimeters that are only a few hours old in the USA (<http://www.geomac.gov>) and in Australia (<http://sentinel2.ga.gov.au/Sentinel/imf.jsp>), earthquakes (<http://earthquake.usgs.gov/eqcenter/catalogs/>), and streamflow and water quality as measured by gaging stations (<http://waterdata.usgs.gov/nwis/rt>). By examining the data on these sites in an inquiry-driven lesson, students gain a deep impression that the Earth truly is a dynamic planet: At some scales and with certain phenomena, the planet changes by the minute.

### *National and Global Mapping Portals*

Other web-based mapping services allow the user to make maps online and download data either dynamically into a desktop GIS or via the conventional method of saving the file and adding it as a map layers. These include portals that are the result of government cooperation and initiative, such as the Geospatial One-Stop (<http://gos2.geodata.gov/wps/portal/gos>). Students can use the Geospatial One-Stop, for example, to examine the changes in the settlement of New Orleans for the past century, and how Hurricane Katrina impacted the landscape. Students can use the National Atlas of the USA (<http://nationalatlas.gov>), the National Map (<http://nationalmap.gov>) to analyze over 200 variables literally from A (agriculture) to Z (zebra mussels).

Other portals are the results of private enterprise and universities. The Geography Network (<http://www.geographynetwork.com>) is a global network of geographic information, users, and providers, allowing students to access maps of themes that they choose, and allowing them to download data. ArcGIS Online is a family of web-based products and services for ArcGIS users, including imagery, political maps, and street maps, among much else. The Globalis Project (<http://globalis.gvu.unu.edu/>) is a collaboration between the Norwegian United Nations (UN) Association, the UN Environment Programme, and several schools and universities in Norway. Students can analyze statistics from the Human Development Report 2003, which is the first global status report discussing how the countries of the world compare in reaching the UN Millennium Development Goals.

For each goal, students can choose between indicators that show the countries' positions as well as examine how each country is making progress toward or moving away from these goals.

### *Mapping History*

Not long ago, the only spatial data online was current, or else, slightly out of date. Increasingly, many Internet GIS services offer historical content, which is of tremendous interest to social studies teachers. The Rand McNally classroom (<http://randmcnallyclassroom.com>) offers historical maps through the US History Atlas and the Goode's World Atlas. Student can examine how landscapes have changed by comparing historical USGS topographic maps (<http://historical.maptech.com>), to current editions (<http://terraserver-usa.com> and <http://www.topozone.com>). Students can do similar work but for a much longer time span via the UK Ordnance Survey's historical maps (<http://www.old-maps.co.uk>) site, and through the Library of Congress (<http://memory.loc.gov/ammem/gmdhtml/>) and the David Rumsey historical library of over 10,000 maps (<http://www.davidrumsey.com>). The GIS for History project (<http://www.gisforhistory.org>) from the University of Illinois at Chicago provides lessons based on historical maps and data within a GIS environment.

### *Virtual Globes*

Another category of Internet GIS services are known as Virtual Globes, so named because they display spatial data on top of a three-dimensional globe on the computer. They represent a combination of a desktop application and content that streams from the Internet. This streamed data does not become resident on the student's computer, but is updated dynamically depending on the scale and geographic area selected. Virtual Globes include but are not limited to ESRI's ArcGIS Explorer (<http://www.esri.com/arcgisexplorer>), NASA WorldWind (<http://worldwind.arc.nasa.gov>) and Google Earth (<http://earth.google.com>). All require a desktop program, but that data streamed from the Internet began with high-resolution satellite imagery that formerly could only be purchased from private vendors as well as elevation data to render the Earth in three dimensions. From these initial data sets, land cover, climate, points of Interest, three-dimensional buildings of the student's own construction, and now, student-created spatial data can be added. For example, ArcGIS Explorer is a small desktop client that accesses ArcGIS Server, a library of spatial data online, in three dimensions. Students can use ArcGIS Explorer to access, integrate, and utilize GIS services, geographic content, and other Web services in a 3-D earth model. This means that student projects that were formerly relegated to be examined in a 2-dimensional GIS can now be analyzed using a 3-D visualization tool. Student content with these tools can be easily shared with others across the Internet, meshing well with the collaborative efforts that many educators are seeking.

## Concluding Thoughts

The abovementioned resources are not just mapping sites, nor are they simply starting points for two components of the geographic inquiry process—acquiring geographic resources, and exploring geographic data. Rather, Internet-based GIS represent opportunities to open up the world of geographic inquiry for students. For example, when students use the National Atlas to investigate the agriculture theme and create a map of cotton production, they can be encouraged to think about the southerly pattern, and connect this pattern to what they know about climate in the southern part of the USA. Next, students can then examine cotton production versus rainfall, and discover that while cotton grows in the south, it does so in areas that receive a moderate amount of precipitation (Georgia, for example) but also in areas that receive little precipitation (central California, southern Arizona, and the Texas panhandle). The teacher can then ask, “How can cotton be grown in Arizona?” and follow this with a value-based question, perhaps the most important of all, “Should cotton be grown in Arizona?”

Essential to successful use of Internet-based GIS in all of these examples is the pivotal role of the educator who is well-acquainted with the themes of the discipline in which he or she is teaching and knows how to frame these inquiry-based questions. Thus, a geography teacher who is familiar with the process of asking geographic questions, acquiring geographic resources, exploring geographic data, analyzing geographic information, and acting upon geographic knowledge (Geography Education Standards Project, 1994), geographic inquiry take advantage of the power of Internet-based GIS to foster inquiry. The same is true of a history teacher who seeks to use these sites for historical inquiry, of a mathematics teacher, and so on. The GIS is a key component in each of the steps in geographic inquiry, not simply as a source of data.

Internet-based GIS will continue to develop at a rapid pace, combining functions from a variety of different services in “mashups.” For these technologies and methods to be adopted in more schools, more research is clearly needed (Baker and Bednarz, 2003). Internet-based GIS are becoming an increasingly easy-to-use and common decision-making tool that requires and fosters spatial thinking that many educators feel must be included in their instruction if society is to solve the complex problems of today and tomorrow.

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## Image Credits

Figure 1. Data from "Global GIS" data set, Europe CD, compiled by USGS and sold by American Geological Institute, displayed in ArcGIS by ESRI, Inc.

Figure 2. The geographic inquiry process graphic from the book *Mapping Our World*, ESRI Press.

Figure 3. Bloom's Taxonomy of six levels of the cognitive domain.

Figure 4. Photograph by Joseph Kerski, Kahului, Hawaii, during a Digital Bus project institute.

Figure 5. GIS analysis shown in ArcGIS software from ESRI, project created by Joseph Kerski for Colorado USA field study exercise.

Figure 6. GIS analysis shown in ArcGIS software from ESRI, data from UK Ordnance Survey for project created by Joseph Kerski for Kent coastal erosion exercise.

Figure 7. Map created by Joseph Kerski with ArcWeb Explorer from ESRI, Inc.

Figure 8. Map created by Joseph Kerski with ArcWeb Explorer from ESRI, Inc.

