Teaching Spatially Integrated Research Methods

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Abstract

Faculty in college-level social science and public policy courses rarely integrate systematic analysis of spatial dimensions of phenomena into their courses or teach students to use GIS software to get answers to social science and public policy questions. Spatial analysis is entirely absent from most social science and public policy research methods courses. But space matters in the issues political scientists, economists, urban planners, public administrators and other social scientists and public policy professionals study. Spatially integrated social science seeks to correct this shortcoming by integrating spatial concepts and GIS operations into social science courses.

This paper describes current efforts to help social science faculty integrate spatial analysis into their teaching and an instructional module the author has developed to teach upper division undergraduate social science students to think spatially, visualize data, and use GIS operations to solve social science and public policy problems. The module integrates urban and regional planning issues, GIS concepts, data graphics concepts, and ArcGIS 9.0 operations to teach social science students to visualize data and think spatially to solve problems.

Instruction in research methods and data analysis is a required part of the undergraduate and graduate curricula of social science and public policy degree programs in the United States and throughout the world. Yet, faculty in college-level social science and research methods courses, with the exception of geography, rarely integrate systematic analysis of spatial dimensions of phenomena into their courses or teach students to use GIS software to get spatial answers to social science and public policy questions. Most social science professors who teach research methods courses are well trained in qualitative and quantitative social science research methodology, have strong analytic skills, and possess solid computer competency. But most simply do not know basic GIS concepts and operations.

Spatial thinking in social science and public policy research

A small number of faculty in each of the social science disciplines and public policy fields have sufficiently mastered GIS concepts and operations to use GIS effectively in their own research and are able to incorporate GIS into their teaching. There is a growing literature by professors in different social science disciplines that provides examples of how GIS can be used in the various disciplines and discusses, more or less explicitly, how spatial analysis can extend understanding in the discipline. GIS is now widely used in policy fields such as epidemiology, criminology, and risk assessment of dangerous areas such as floodplains and earthquake fault lines.

Mapping attributes of the human population is a valuable tool for sociologists and for demographers, who are often trained as sociologists. Social issues often have a spatial dimension and understanding how to use census and related demographic data in a GIS can contribute to sociological analysis (Brewer and Suchan 2001, Peters and MacDonald 2004).

Anthropologists can map patterns of kinship, religious belief, and other behaviors (Aldenderfer and Maschner 1996). Archaeologists can map archaeological sites at different scales. CAD and GIS are increasingly used for small scale site maps where keeping track of the precise location of artifacts is essential. At more macro levels GIS can be used to map attributes of civilizations and their relationship to the natural landscape and other civilizations at one point in time or over time.

Political scientists can map voting outcomes, use GIS to assist in redistricting, and map political attributes of countries, states, counties, and precincts (Ward and John O'Loughlin 2002). GIS is an important tool in assessing voter opinions and developing strategy for political campaigns. Local government officials and policy analysts often encounter spatial aspects of public policy issues (O'Looney 2000).

Historians can use spatial analysis to analyze everything from the where people accused of being witches during the Salem witch trials lived to the route of the Lewis and Clark expedition (Knowles 2002).

City and regional planners deal with physical space. They must understand spatial relationships between land use and transportation in the cities and regions they are planning. Spatial analysis of planning issues can help them plan more effectively (Huxhold, Fowler, and Paar 2004). Planning support systems can inform their practice (Brail and Klosterman 2001).

Initiatives to extend spatial analysis in social science research

There are a number of national initiatives to support the innovative use of spatial analysis in social science research instruction and better equip social science students to do spatial analysis.

Supported by a grant from the National Science Foundation, faculty associated with U.C. Santa Barbara's Center for Spatially Integrated Social Science (CSISS) in collaboration with faculty at the University of Ohio and other colleges and universities have been engaged in a range of activities to foster the integration of spatial considerations into social science research and teaching (http://www.CSISS.org). CSISS has trained and supported graduate students to teach them to incorporate spatial analysis into their research, Ph.D thesis research, and teaching. CSISS maintains an excellent set of web based resources for teaching spatially-integrated social science, supports demonstrations of GIS instruction at social science conferences, and fosters the exchange of information among social science faculty interested in spatial analysis. Beginning in summer 2004, CSISS has conducted summer workshops to train social science faculty in spatial analysis. One of the CSISS summer workshops each year is sponsored by the University Consortium for Geographic Information Science (UCGIS). An anthology co-edited by the key faculty associated with CSISS—University of California Santa Barbara geography professors Michael Goodchild and Donald Janelle—contains exemplary work by social scientists using spatial analysis in their work (Goodchild and Janelle 2002).

The National Institute for Technology in Liberal Education (NITLE), with the support of a Mellon Foundation grant, currently has an initiative to disseminate understanding of GIS to faculty of 91 liberal arts colleges (http://www.nitle.org/). NITLE is conducting workshops to teach GIS and spatial analysis to social science faculty in liberal arts colleges.

The Academic Excellence and Geographic Information Systems (AEGIS) Project at Samford University is a NSF-supported three-year (2003-2006) multidisciplinary effort to introduce students in a variety of lower division Arts & Sciences courses to methods of GIS data gathering, analysis, and representation (http://www.samford.edu/ schools/artsci/geography/aegis). Faculty from the Samford geography department conduct summer training sessions for Samford faculty from a variety of social science disciplines and continue to provide technical support as the faculty and their students carry out research projects using GIS during the academic year.

The NSF-funded Space, Culture, and Urban Policy project at San Francisco State University is developing instructional modules to teach social science faculty spatial analysis and data visualization (http://bss.nsfgis.index.htm). The instructional module titled *Think Globally, Act Regionally* by the author has been developed with support from this grant. SFSU Urban Studies Professor Ayse Pamuk is developing a companion instructional module titled *GIS Methods in Urban Analysis: A One World approach* (Pamuk forthcoming 2006).

Models of social science GIS instruction

Professors and others have developed four main pedagogical models for teaching GIS and spatial thinking. Professors employing the models do not necessarily call them by the names employed below and many professors are not conscious of the model choice(s) they have made. Many professors mix more than one model in their approach to instruction, consciously or unconsciously. Additional pedagogical models for teaching GIS exist and are being developed.

The GIS operations model.

Unless students master GIS *operations* they cannot incorporate GIS into their research. Almost all instruction in GIS involves a component to teach GIS operations: the actual steps necessary to perform GIS analysis and produce maps and other spatial analytic output. The main method to teach GIS operations is through “step-by-step” exercises. Most social science professors are familiar with this method of teaching computer skills. It is similar to the approach social science faculty use to teach statistical package software. Most software companies and third party authors of software “how to” manuals use the step-by-step method to teach people to use computer software. In the case of GIS, most step-by-step instruction requires existing datasets as well as hardcopy or virtual instructions on the appropriate steps to follow to accomplish a specific set of GIS operations.

ESRI's *Getting to Know ArcGIS* 2nd ed (Ormsby, Napoleon, Burke, Groessel, and Feaster 2004) is the most widely used text for teaching GIS operations. *While Getting to Know ArcGIS* 2nd is an excellent example of the step-by-step pedagogical model for teaching software operations it has limitations as a vehicle for teaching GIS and spatial analysis in the social sciences.

The great strength of the GIS operations model is that it provides students the tools they need to do spatial analysis themselves. Teaching GIS operations is essential if students are to be able to actually use GIS to do research. The principle criticism of the GIS operations model is that it focuses on ephemeral operations rather than fundamental concepts: an approach that has been criticized as "*tool-centric*" (Hall and Walker 2005). Another problem with the GIS operations model is that GIS software is evolving so rapidly that whatever set of operations a student is taught will be obsolete within a few years. Unless students learn underlying concepts, what they learn will be of little enduring value. A final limitation of a pure operations-based model for introducing GIS and spatial analysis in social science research methods classes at the present time is the absence of step-by-step teaching materials that address social science concerns. While the subject matter of *Getting to Know ArcGIS* is varied and interesting, this book is not primarily focused on social science concerns. Other step-by-step materials for teaching GIS are too specialized to be appropriate for introductory social science research methods courses.[1]

The GIS concepts model

Basic education in GIS should teach enduring GIS and spatial analysis concepts. Addressed to social science students who have not taken geography courses, basic education should include conceptual material on matters such as map projections that are ordinarily assumed in beginning GIS classes in geography departments. Mark Monmonier has written two excellent overviews of this material aimed at social scientists who are not trained as geographers (Monmonier, 1993, Monmonier, 1996). Appropriately, the standard introductory GIS texts are designed to teach underlying GIS concepts (Bernhardsen 2002; Bolstad, 2003; Chrisman 2003; Clarke 2002; Demers 2002; Heywood, Cornelius, and Carver 2003; Longley, Goodchild, Rhind 2003).

As a pure model for social science spatial analysis and GIS education, the GIS concepts model is superior to the GIS operations model. The great strength of the GIS concepts model is that it provides a foundation of basic understanding that can guide students' further learning. Concepts related to georeferencing, map projections, precision, accuracy, scale, classification, query logic, the modifiable area unit problem, spatial coincidence, and the like will not become obsolete as GIS software evolves. GIS software has incorporated many of the principles that cartographers have developed over centuries. Students in social science research methods classes who receive only a single lecture on GIS and spatial analysis concepts will at least be exposed to an important body of knowledge that they should be aware of and which will remain relevant for a long time. Equipping students with concepts and examples of GIS maps and spatial analysis output may help lay the foundation for further study and may encourage some students that would not otherwise consider taking course(s) in GIS to do so. But without being taught GIS operations, they will not be able to use GIS for their own research. They will be in the same position as students who hear lectures about exotic and complex technology without being able to engage with the technology itself. This is a common limitation in introductory science courses, where student may hear lectures about linear accelerators or the expensive medical imaging technology, but because of cost limitations never use the equipment itself.

There are a number of arguments against using the GIS concepts model alone. First, there is a reciprocal relationship between concepts and operations. In GIS instruction hearing a lecture about an abstract GIS concept such as kernel density or inverse distance weighted interpolation involves material that is foreign to students' experience. Hearing a lecture, doing a lab, and then engaging with more conceptual material helps students digest and assimilate concepts. Particularly when the output from operations is visual, learning by doing reinforces conceptual lectures. Secondly, the cost-related reason for not exposing students to GIS technology is becoming less and less compelling. Twenty years ago GIS technology was in the position that linear accelerators and medical imaging technology are in today: so expensive that it was not practical to let beginning students use the technology. Today GIS software is widely available at colleges and universities on networks that make the software accessible on personal computers in university computer labs. A final objection to using the GIS concepts model alone is that the GIS concepts model raises the prospect of frustrating the students, rather than motivating them. Having seen what GIS can do, students will want to be able to do it themselves. Just telling them that it is possible to create exciting analytical maps with computers and showing them some stunning examples is not enough.

The Teach with GIS Model.

A third model attempts to exploit the power of GIS technology and also involve students in research, but not to teach either GIS concepts or operations. It may be termed the "teach with GIS model". This model views GIS as a vehicle for allowing students to explore data. The SAGUARO (Science and GIS: Unleasing Analysis and Research Opportunities) project developed an excellent instructional module that uses GIS to teach earth science materials for introductory-level undergraduate and secondary school students using ArcView 3x (Hall-Wallace, Butler, and Kendall 2002). The SAGUARO project did not attempt to teach GIS operations. Its substantive focus was on teaching students about earth science (plate tectonics, earthquakes, volanos, tsunamis and related material)—not GIS concepts or operations. The SAGUARO materials teach students to use GIS like a web browser to find information. Professor Andrew Beveridge at New York University has created a searchable, web-based data set on the changing demography of New York and other U.S. cities over time named social explorer (http://www.social.explorer.com). Social explorer organizes an enormous amount of interesting demographic data and provides web-based tools that allow unskilled users to explore the data. It is a powerful resource in allowing students to zero in on a geographical area of interest such as their own neighborhood and see how its demographics have changed over time. In addition to its inherent value as a research tool, this may inspire students to learn more about GIS. Social explorer is not a vehicle for teaching GIS concepts or operations.

A holistic model for teaching Spatial Analysis

Perhaps the best approach to teaching spatial analysis and GIS to social science students in research methods courses involves a judicious blend of all of the above models. Careful selection of what material to present is critical given the extent of what might be taught and time limits faculty teaching introductory research methods courses face. Most undergraduate research methods courses consist of a single 10 or 15 week course that must cover a variety of qualitative and quantitative topics. It is unlikely (and undesirable) for GIS to displace such conventional social science methods course topics as survey research, observation, interviewing, focus groups, and quantitative analysis using the Statistical Package for the Social Science (SPSS) or other statistical software.

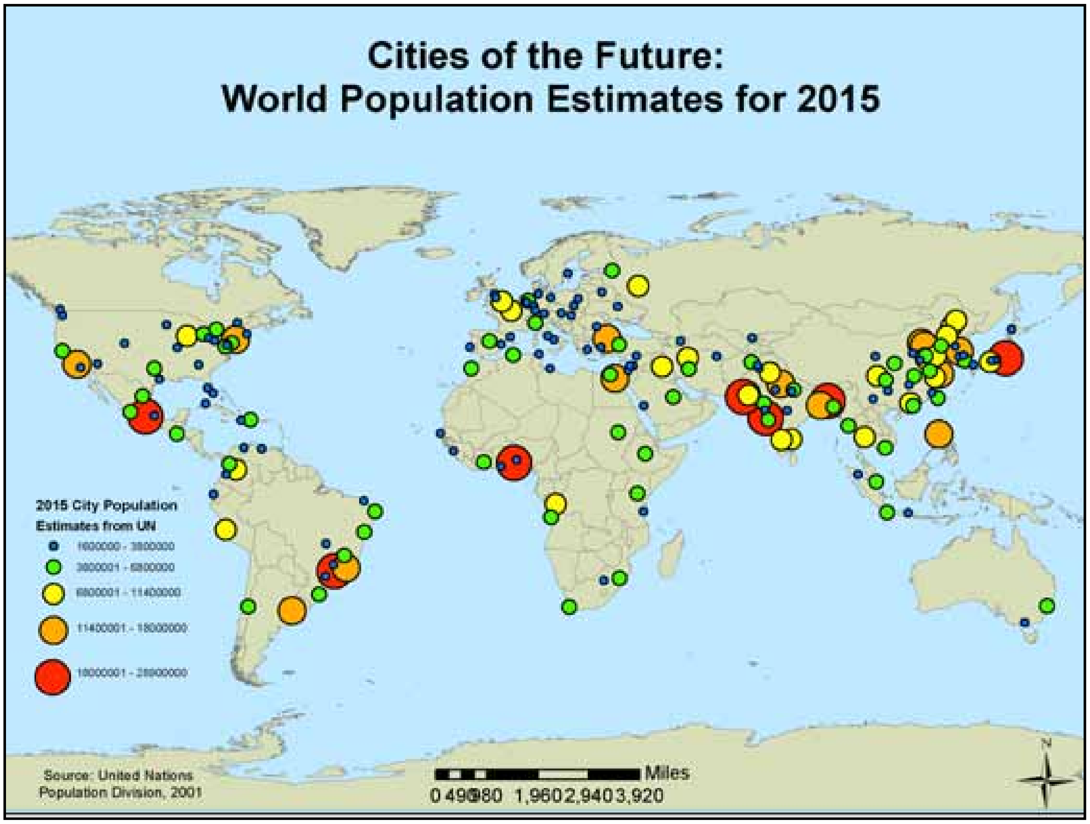
One attempt to create an instructional module that blends elements of each of the above approaches is *Think Globally, Act Regionally* (LeGates 2005): an instructional module consisting of a softback book and accompanying CD-ROM with data sets. A companion volume by Ayse Pamuk titled *GIS Methods in Urban Analysis*: *A One World Approach* (Pamuk forthcoming 2006) uses a variation of this model. Most of *Think Globally, Act Regionally* consists of chapters describing the way in which GIS and spatial analysis can be used to address urban issues and material on GIS and data visualization concepts. Step-by-step exercises in the back of the book articulate with the substantive material and concepts introduced in the book. Students using this module draw on data sets that were used to create the maps and spatial analytic output in the book. In the exercises they, themselves, create maps that are similar to, and in some cases identical to, maps in the book. Following is a description of the principle features of the *Think Globally, Act Regionally* holistic model.

Issue-based instruction

An earlier publication by this author (LeGates 2005) argues that most under-graduate social science majors take methods courses only because they are required and often approach them with a mixture of fear and apathy. Moving immediately into difficult conceptual GIS material that students view as far removed from the interests that drew them to the social or policy sciences is intimidating and students question its relevance. Accordingly it is very important to use substantive material that students can relate to in teaching spatial analysis. Social science students could be taught GIS concepts and operations using material from marketing or earth science just as they can be taught statistics using examples from these fields or abstract examples involving tossing pennies and drawing marbles out of a hat. However, students' interest is related to the underlying subject matter. How receptive they are to conceptual and technical material depends on how relevant they consider it to be to their concerns. If they are not interested in drawing marbles out of a hat or understanding earth science they are not receptive to the concepts.

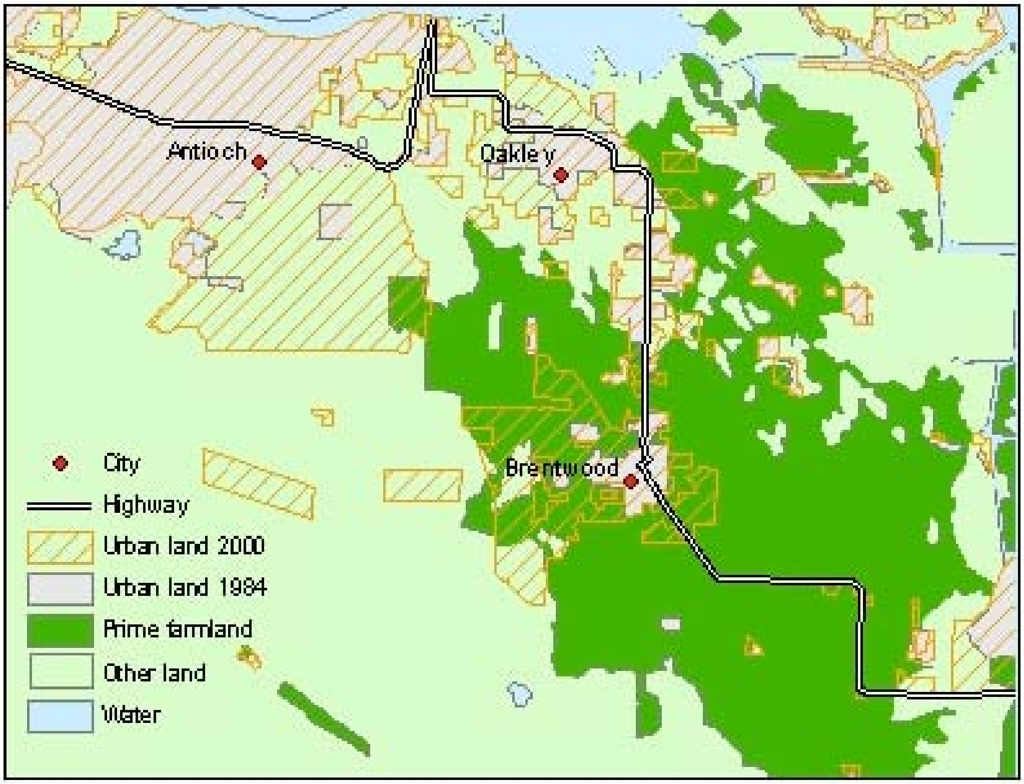
Think Globally, Act Regionally uses substantive material related to urbanization and its consequences at different scales, from the global to the very local. Much of the material focuses on regional level urban analysis. Sub themes within this material were selected based on interests of students at San Francisco State University and other universities around the United States where the module was tested.[2] A companion volume by Ayse Pamuk, *GIS Methods in Urban Analysis* (Pamuk forthcoming 2006) uses substantive material on world urbanization, the location of Head Start centers for pre-school children, immigrant clusters in U.S. cities and other material students have found of interest. *Think Globally, Act Regionally* is divided into four parts. Each part is designed for a week or more of classroom lectures and computer labs.

The first section of *Think Globally, Act Regionally* focuses on urbanization and the problems and opportunities urbanization brings. It draws on data on the population of world cities at different times in human history assembled by Tertius Chandler and Gerald Fox (Chandler and Fox 1976, Chandler 1983), data from the population division of the United Nations on the population size of urban agglomerations in 2000 (UN 2003), World Bank data on urbanization (World Bank 2004), and a classification system developed by academics associated with the Global Cities Working Group and Network at Loughborough University in the UK to discuss the growth of cities and world city size today. The first part of *Think Globally, Act Regionally* also uses material from the U.S. census related to foreign-born residents of the San Francisco Bay area, commuting behavior, poverty, and affordable housing to teach about urban issues and how spatial analysis can be used to better understand them. Map 1 illustrates UN population estimates for large world cities in 2015 used in the book and exercises.



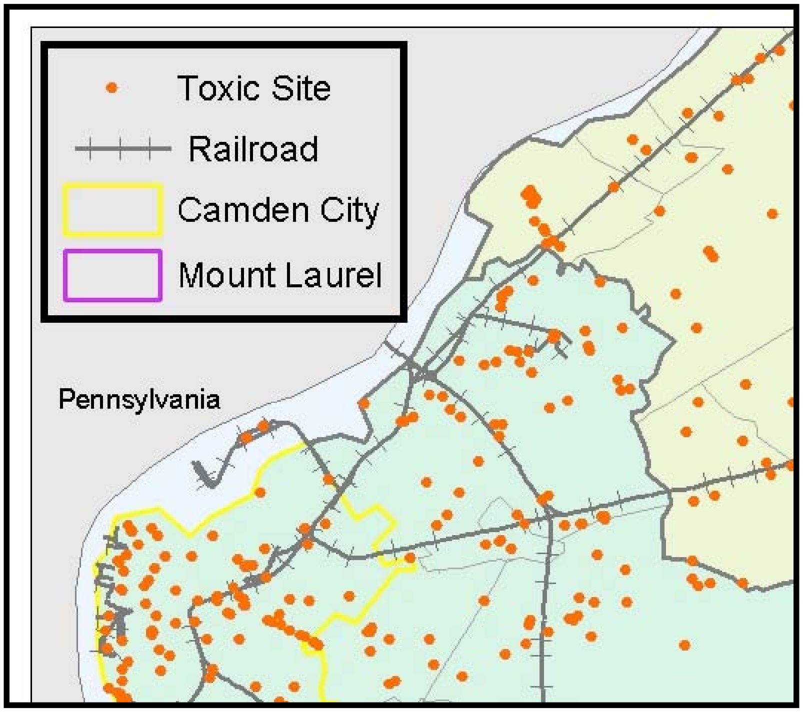
Map 1
Estimates of the size of large world cities in 2015
Source: Richard LeGates, *Think Globally, Act Regionally*

The second part of Think Globally, Act Regionally deals with conflicts between the built and natural environment in Contra Costa County, California. It uses data on endangered species from the California Gap Analysis Project (CA-GAP), the California Air Resources Board on ozone pollution, the U.S. Environmental Protection Agency on toxic releases, the California Department of Conservation's Farmland Mapping and Monitoring Program on farmland at different time periods, and other data. Map 2 illustrates the impact of urbanization on prime farmland in Contra Costa County, California discussed in the book and used in the exercises. Students can readily identify with loss of natural resources such as prime farmland and understand how urbanization is reducing farmland. They can see how a map like Map 2 can clarify the nature of this conflict between the built and natural environment. Once this connection has been established, students welcome more conceptual material related to map symbology. Lecturing about a topic such as superimposing a layer symbolized with hatch marks over a layer with a solid color that would make little sense to them in the abstract becomes a matter of interest to them.



Map 2
Urbanization and loss of prime farmland in
Contra Costa County, California
Source: Richard LeGates, *Think Globally, Act Regionally*

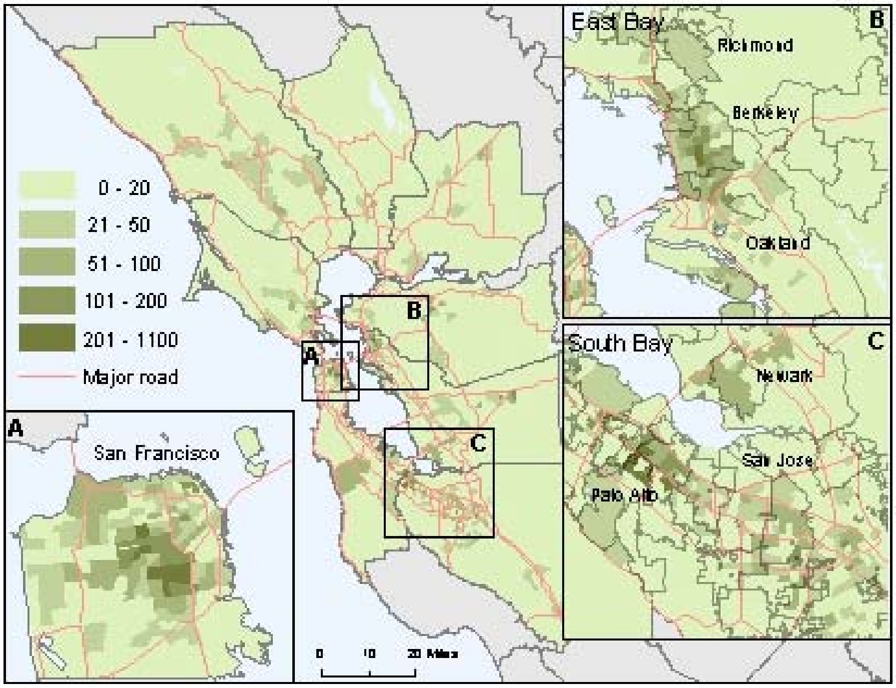
The third part of *Think Globally, Act Regionally* deals with regional equity issues in Camden and Burlington Counties, New Jersey. It draws heavily upon work by University of Minnesota Law Professor Myron Orfield (Orfield, 1999, Orfield 2002, Orfield and Luce 2003). This part of the module discusses differences in the racial composition of high school student bodies, differentials in municipal tax rates and funding for public services, the location of affordable housing in relation to jobs, the location of contaminated sites in relation to low income and minority neighborhoods, and other equity issues. Because college students themselves have recently experienced the demographics of their own high school, are beginning to think about where they can afford to purchase a house when they complete college, and are often passionately concerned about environmental justice issues, this kind of regional equity issue again draws them into more conceptual material on analyzing spatial inequality and regional integration and, in turn, the operations necessary to create maps that show differences in the income and race of students at different schools in a region, how much more or less tax revenue some jurisdictions can raise than others, the lack of affordable housing near some job centers, and whether or not contaminated sites are disproportionately located near low-income and minority communities. Map 3 illustrates the location of sites that the New Jersey Department of Environmental Protection has identified as having groundwater contamination as of 2001 that is used in Part 3 of *Think Globally, Act Regionally.*



Map 3
Sites with groundwater contamination near Camden, N.J.
Source: Richard LeGates, *Think Globally, Act Regionally*

Moving from Interesting Substance to Visualization to Concepts

If the ultimate goal of GIS and spatial analysis education is to teach students concepts, and the beginning point is substantive material that interests them, one additional intermediate step is useful. Rather than moving directly from substantive material that interests undergraduate social science students to concepts, it is useful to provide maps and other visual images as a bridge to illustrate how GIS concepts can help students create maps that they, themselves, find interesting. Map 4 is a thematic map showing information on the number of people in the San Francisco Bay Area over the age of 16 who bicycled to work in 2000 that appears in *Think Globally, Act Regionally*. Students find the subject matter (bicycling to work) inherently interesting and can immediately see patterns in the maps. They are motivated to create maps like this themselves and will ask: "how do I create a map like that". That is the point at which to introduce concepts such as what elements to include on a map layout, appropriate choice of colors to symbolize the map, map labeling, and how to construct a map legend. Cartographically Map 4 has much to offer students concerning how to symbolize good thematic maps.

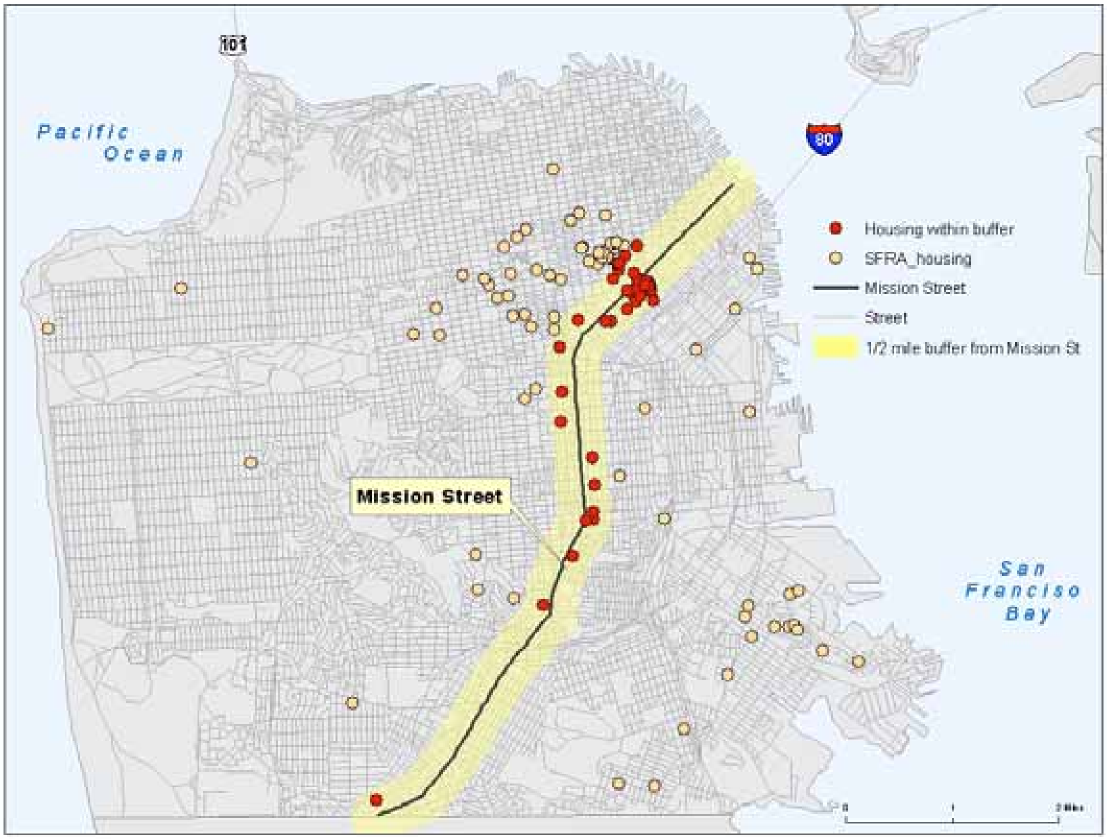


Map 4
Number of people age 16 and over who bicycled to work in 2000
Source: Richard LeGates, *Think Globally, Act Regionally*

Combining content, concepts, and operations

Neither the *operations model* or the *GIS concepts model* alone is a fully satisfactory approach to teaching GIS and spatial analysis to social science students—even elementary GIS that must be introduced in no more than a few weeks of an introductory social science research methods course. It is important to have relevant social science content combined with material on both concepts and operations.

The approach that *Think Globally, Act Regionally* takes is to structure each of the first three parts of the book to include an opening chapter on an important subject (urbanization, built/natural environment conflict, regional equity) and then to follow with chapters on GIS and data visualization concepts using material and maps related to that theme. For each section of the book exercises allow students to work with data sets that form the basis for the text discussion and maps in the book. Six step-by-step exercises: (1) introduce basic GIS operations using vector GIS, (2) teach students to query and classify spatial data, (3) introduce the raster GIS model, (4) teach students to create a suitability model, (5) instruct students on appropriate map symbology, and (6) teach them to create professional map layouts. The final exercise provides data from a very rich data set—the Regional Land Information System (RLIS) Lite data set created by Metro in the Portland, Oregon region. Map 5 illustrates symbology concepts *Think Globally, Act Regionally* teaches: differentiating point symbols, labeling features, and creating transparent layers.

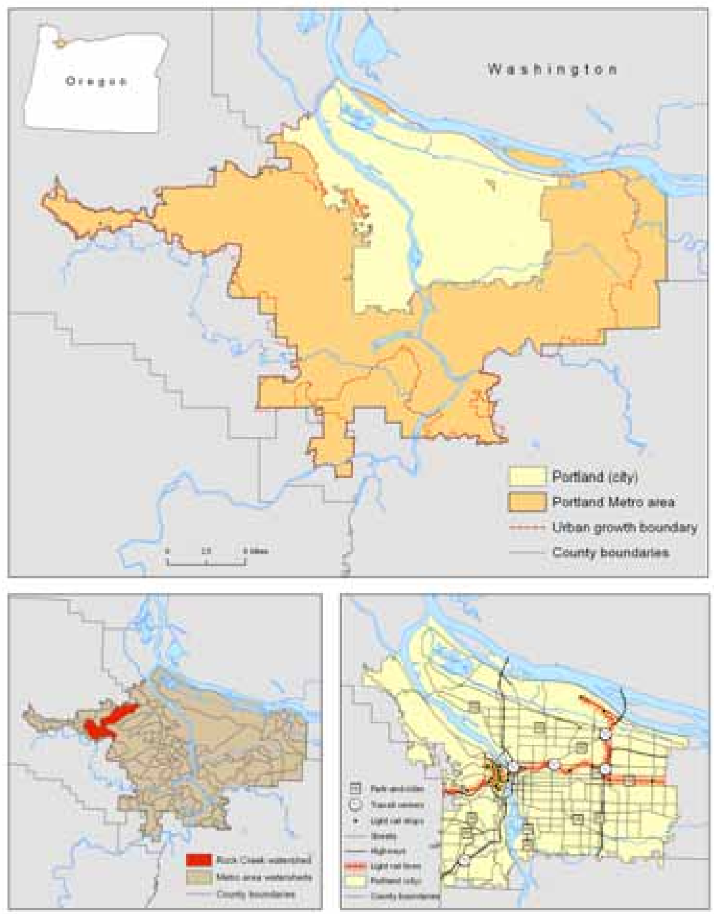


Map 5
Housing Assisted by the San Francisco Redevelopment Agency
Within _ mile of Mission Street
Source: Richard LeGates, Think Globally, Act Regionally

Recursive learning of concepts and operations

Learning GIS concepts and operations is not like the kind of learning that occurs in a general education class surveying masterworks of American literature. In that kind of a class students may at least get by if they read required books once just before the final exam. Mastering GIS concepts is more like the kind of learning that occurs in a math or physics course in which concepts must be practiced and learning is cumulative.

The approach to teaching GIS operations in *Think Globally, Act Regionally* is first to set the background through the urban issues chapter and a chapter on GIS concepts and then to have students complete exercises that cement the concepts. Each exercise in *Think Globally, Act Regionally* has an explicit statement of learning objectives. About twenty-five steps take students through a set of GIS operations. At the end of each exercise is a section titled "Your Turn" which requires students to go back over the operations they have just learned with the step-by-step method and re-do them with a different data set and without step-by-step hand holding. Students are encouraged to re-read the conceptual chapters after they have completed exercises related to them. The final exercise asks students to integrate what they have learned by doing spatial analysis related to regional urban growth management, regional transportation planning, regional environmental analysis, or regional water-related risk management and environmental education using data from Metro’s Regional Land Information System Lite database. Some of the spatial data in the RLIS database is illustrated in Map 6 below.



Map 6
Urban growth management, transportation, and water-related risk management and environmental education issues in the Portland, Oregon region.
Source: Richard LeGates, *Think Globally, Act Regionally*

Both vector and raster

An important choice instructors teaching introductory GIS classes must make is to what extent to teach about raster as well as vector GIS. Most social scientists use vector GIS—particularly with polygons based on U.S. census area definitions: blocks, block groups, census tracts, Public Use Microdata Areas (PUMAs), urban areas, counties, and States. Within these clearly defined units that are well represented as vector GIS polygons, social scientists and public policy professionals can teach students to analyze census data on race, income, gender, homeownership, carpooling, and hundreds of other variables. Clearly defined polygons work well for analyzing voting behavior. Raster GIS is superior for analyzing continuous surfaces and is particularly appropriate for many kinds of analysis of the natural environment that are of interest to social scientists and public policy professionals. In Geography departments, raster GIS is often taught as a separate and more advanced topic after students have completed an introductory course mostly or exclusively based on the vector GIS model. The basic text on raster analysis (Demers 2001) is too advanced for use in part of a social science research methods class.

Think Globally, Act Regionally introduces both the vector and raster GIS models. In a course with extreme time limits this decision comes at some cost. Devoting time to introducing a second conceptually and operationally complex GIS model necessarily requires cutting out additional vector GIS topics that could be explored in greater depth if the raster GIS model was not included.

Emphasis on analysis

Mastering GIS is a major undertaking. Geography departments now typically offer a sequence of courses on GIS and remote sensing. The University Consortium for GIS (UCGIS) has developed an entire four-year model curriculum to teach undergraduate students GIS (UCGIS 2004).

Because *Think Globally, Act Regionally* is designed to be completed in just part of a single upper division undergraduate social science research methods course, it cannot include as many topics as would be covered in a full GIS curriculum or even an introductory GIS course. The choice to introduce the raster model, as well as the vector model, further constrains the amount of time available to teach all of the operations it would be desirable for beginning students to know in order to do elementary GIS on their own. A further choice involves emphasizing analysis at the expense of data acquisition and management.

A common, and extremely valuable, skill that is often taught in beginning college GIS classes (and many K-12 classes) involves data collection in the field. For example students may take water samples from a local river, analyzing them in a laboratory, input data on attributes of the water into a form readable as a GIS attribute table, link the table to a map, and then analyze the results using GIS. Going through an exercise like this will teach student about scientific measurement, sampling, data entry, operations necessary to link quantitative data to maps, and spatial analysis. But this is a time consuming process that can easily consume an entire course. Social science students could be taught social science research in a similar way by, for example, going to liquor stores in their community with a GPS receiver, measuring attributes of the liquor stores, inputting the data, linking the data to a map, and analyzing it. *Think Globally, Act Regionally* does not teach this skill. It omits material on editing spatial data, geocoding, managing data (using ArcCatalog), creating personal databases, and many other topics. Some of these topics are covered in Ayse Pamuk, GIS Methods for Urban Analysis: A One World Approach (Pamuk forthcoming 2006).

The underlying theory driving the selection of topics in *Think Globally, Act Regionally* is to produce the best set on materials possible for a one-month part of an upper division undergraduate social science research methods course to teach students data analysis and data visualization. There is a large literature on data visualization and one scholarly and accessible introduction to GIS data analysis (Mitchell 1999). Data acquisition and manipulation are very valuable operational skills, but given a choice between more time spent on analysis and less on data acquisition and manipulation *Think Globally, Act Regionally* favors analysis.

Integrating GIS with data graphics and statistical analysis

A final theme in *Think Globally, Act Regionally* involves the relationship between GIS and other ways of analyzing data and communicating research results. In addition to the material on GIS, *Think Globally Act Regionally* contains three chapters on data graphics and data visualization. There is a well developed body of knowledge about how to create professional data graphics to visually communicate statistical and other information (Cleveland 1993, Cleveland 1994, Harris 1996). The chapters on data graphics in *Think Globally, Act Regionally* use the same data that is used to create maps in the book to teach students how to create data graphics to display the results of data analysis. The first of the three data graphics chapters describes common univariate data graphics—pie, bar, line, and column charts and histograms. The second chapter describes common bi- and multivariate data graphics: multi-bar, multi-line, and area charts, scattergrams, and stacked bar charts. A final chapter deals theories of visual communication (Bertin 1976, Tufte 1997, Tufte 2001, Tufte 2002). Figure 1 illustrates some of the data graphics in these chapters.

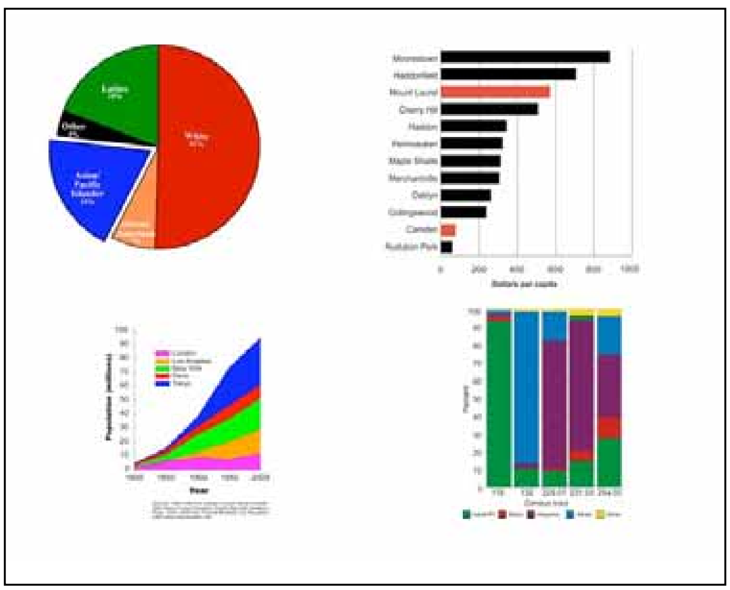


Figure 1
Illustrative data graphics from *Think Globally, Act Regionally*
Source: Richard LeGates, *Think Globally, Act Regionally*

Students should be able to see the relationship between spatial representations of phenomena in maps and representations of the same phenomena using data graphics.

Figure 2 is one example from *Think Globally, Act Regionally* illustrating the connection between maps and data graphics. The two maps show the number of people age 16 and over who drove alone and who carpooled to work in the form of a map in which the location of census tracts is emphasized. The multi-bar chart below the two maps provides an aspatial representation comparing driving behavior in the two tracts.

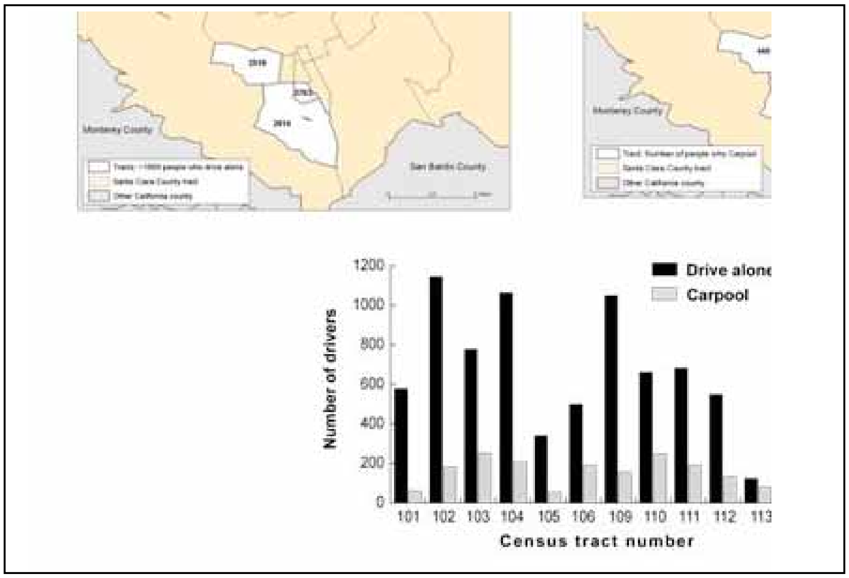


Figure 2
Maps and a multiple-column chart illustrating
carpooling and driving alone in Southern Santa Clara County California
Source: 2000 U.S. Census of Population and Housing

Beginning social science research methods courses and companion social science data analysis courses commonly introduce students to statistics using the Statistical Package for the Social Sciences (SPSS), SAS, STATA, MiniTAB or some other statistical package. Some social science research methods courses teach students to use spreadsheets such as EXCEL. *Think Globally, Act Regionally* discusses “loosely coupled” analysis—the passing of data back and forth between GIS, statistical packages, spreadsheets, and other software. Figure 3 illustrates this concept.

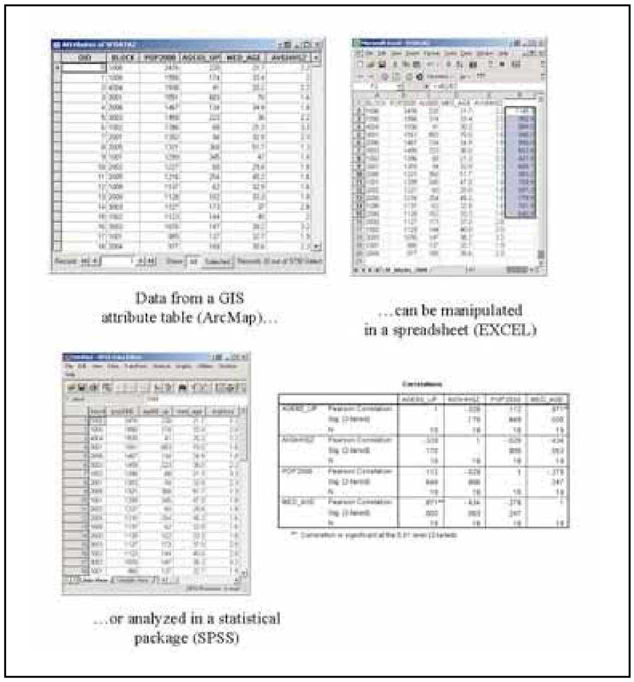


Figure 3
Loosely coupled analysis using GIS,
spreadsheetsand statistical packages
Source: Richard LeGates, *Think Globally, Act Regionally*

Conclusion

GIS is an exploding area of human knowledge. Pedagogy to teach GIS is expanding and evolving rapidly as professors struggle with the best way to communicate this complex material and explain its relevance to different disciplines and professional fields. There are many different ways to teach GIS. This paper has described one attempt to implement a holistic model for teaching GIS and spatial analysis to upper division undergraduate students in social science research methods courses. It draws on work others have done to develop a number of different pedagogical models. The results is one systematic attempt to provide substantive material that undergraduate students find interesting at an appropriate level, fundamental vector and raster GIS concepts, and exercises to teach GIS operations. The approach reflects the author's experience teaching undergraduate students at San Francisco State University, and feedback from social science faculty around the country grappling with the important issue of how best to introduce social science students go GIS and spatial analysis.

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Footnotes

[1] Other books published by ESRI Press such as *Digital City* (Huxhold, Fowler, and Parr 2004) include also exercises and step-by-step instruction. ESRI in person training and ESRI virtual campus courses and workbooks teach GIS operations using the step-by-step approach.

[2] A beta version of the Think Globally, Act Regionally module was tested during fall 2004 at San Francisco State University, The University of Massachusetts Amherst, and Medgar Evers College.