A Case for Teaching Geographic Visualization without GIS

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This article argues for the value of teaching geographic visualization to non-geography majors by having them make maps manually, using punched mylar, colored pencils, and light tables instead of computer-based geographic information systems or mapping programs. The essay contrasts the experiences of attempting to teach principles of geographic visualization using ArcView GIS in an introductory human geography course and using manual methods in an upper-level research methods course in history. Several conclusions emerge: (1) using manual methods to visualize spatial information quickly gets students thinking geographically; (2) the ease of learning the fundamental concepts and techniques of geographic visualization using manual methods makes it possible to integrate visualization into courses outside the discipline of geography; (3) geographic visualization can tremendously enrich the study of history, prompting students to think in ways they might not otherwise; and (4) teaching visualization with mylar has distinct advantages for history courses because physical map layers reinforce the notion that places are palimpsests of change. Manual methods make it possible to teach geographic visualization at colleges and universities that have no geography department or GIS courses. Their use should be encouraged as an adaptable, inexpensive, effective way to promote geographic learning and geographic literacy in U.S. higher education.

KEYWORDS: geographic visualization, mapping, GIS, history.

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Among academics, geographic visualization is rapidly supplanting cartography as the key term for a range of methods, skills, and intellectual and aesthetic goals for rendering spatial data. The term appeals because it encompasses traditional and computer cartography as well as geographic information systems (GIS) and sweeps them all into the broad, fast-moving currents of scientific visualization. Geographic visualization makes intuitive sense to all generations of geographers and cartographers, whatever their personal skills and predilections, because geography is inherently a visual way of knowing.[1] Alan MacEachren and others have argued that scholars' new interest in visualization represents a technical and philosophical revolution. Visualizing spatial data is no longer simply making maps. It is now an exploratory tool for interrogating data, developing research hypotheses, "extracting patterns from chaos."[2] For all its technical sophistication, geographic visualization is also central to recent pedagogical and curricular developments that in some ways are returning geography to its empirical roots in mapping.

Geography departments across the country are creating courses in "geotechniques" or "geographical information," which include various combinations of training in fundamental geographic concepts, Web-based geographic information, geographic visualization, and GIS. There is now a firm curricular position for introductory courses that lay the groundwork for advanced study of geographic visualization and GIS, which are increasingly considered indispensible for geographers. These course

sequences are proving popular among geography majors and other students, in part because of the job-market value of GIS skills. The greatest latent demand for learning about geographic information and visualization, however, lies outside of geography, in departments whose students are not exposed to geographic concepts and at institutions that have no geography program.

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I will argue in this essay that fundamental concepts of geographic visualization can be taught without reference to GIS or computer technology. The barriers against entry into the worlds of GIS and high-tech geographic visualization remain very high at colleges and universities that have no geography department or other program that offers instruction in the technology. I encountered those barriers, like a Sunday jogger attempting a steeplechase, when I came to Wellesley College to teach an introductory course in geographic concepts and GIS in the fall of 1997.

DIFFICULTY OF TEACHING GIS OUTSIDE A GEOGRAPHY DEPARTMENT

The course I was asked to design was intended to address three initiatives undertaken at Wellesley College shortly before I arrived. The first was a new quantitative reasoning (QR) requirement meant to ensure that every Wellesley student mastered elementary statistical concepts at some point in her four years of undergraduate education. My human geography course was to be one of several "QR overlay" courses in which students learned basic statistics in the context of a substantive field of study. I chose to focus the statistical content of the course on analyzing social inequality as represented in the 1990 U.S. population census. The second initiative was to promote the use of computer technology in classroom teaching, which I aimed to do by using ArcView GIS as a tool for visualizing census data and producing maps showing the results of simple statistical analyses. The third initiative was a diffuse interest in globalization, which certain members of the faculty and administration thought could be brought into focus partly through my activities on campus, including the courses I would offer in geography.

While the opportunity to introduce GIS was exciting, a number of factors made the challenge more difficult at Wellesley than it would be at some institutions. The fundamental problem was the lack of library and technical resources to support geographical studies and GIS, due to the College having eliminated its Geography major in 1965.[3] No Wellesley faculty used GIS in their teaching, though a few had begun to use it in their research by the late 1990s. Shortly before I came in 1997, the College acquired a site license for ArcView GIS, but its restrictions limited the program to a few library and classroom computers and provided minimal technical support. The course was also over-burdened with material, for the statistical and GIS component was to account for only one-third of course content, the remainder going to an orthodox introduction to human geography.

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In the course debut as Extradepartmental 110: Introduction to Geographic Concepts, I introduced ArcView in three take-home exercises that asked students to apply the skills they learned from tutorials in ESRI's *Getting to Know ArcView GIS*[4] to prepared 1990 census data at the tract level for Los Angeles. Most students sailed through the tutorials but found it much more difficult to use ArcView to interrogate the census data – as did I. I spent about one hundred hours preparing the data and creating the ArcView exercises. The students found ArcView to be an unwieldy and frustrating tool, largely, I believe, because I had not provided them with sufficient context and principles to understand the structure of GIS or its usefulness in analyzing social statistics. ("In my experience," geographic educator David DiBiase wrote recently, "students who are not provided with the clearest possible sense of the connection between principles

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and practice are likely to conclude that principles are irrelevant."[5] The converse also holds true: students who do not understand principles are unlikely to be able to practice what they learn.) The site license restrictions also limited students' access to the program for homework assignments and class projects. It was not a happy experience for anyone, although enough of the students appreciated the inherent interest of GIS to encourage me to try again.

The second incarnation of the course, as Sociology 140: Geography and Society, was much more successful. I introduced ArcView after teaching several sessions on general concepts in statistical thematic mapping, which helped integrate the technology into the larger themes of the course and prepared the students to think critically about the data they used and the maps they produced. I also changed the assignments from individual take-home exercises to an exploratory Web-based team project in which only one of four self-selected groups of students used ArcView extensively. The project's purpose, to create a virtual geographical tour of Boston, also appealed to students' local interest. The ArcView group surprised themselves and the class by mastering GIS sufficiently to produce a series of compelling maps of neighborhood segregation and social inequality. Despite these improvements, the course still left students and me unsatisfied because the time given to teaching technology (which now included Claris Homepage as well as ArcView) short-changed conceptual content.

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FINDING THE ESSENCE OF GEOGRAPHIC VISUALIZATION

I had not yet found a way to teach principles and skills of geographic visualization within the context of another subject. A third opportunity to do so came in an upper-level research seminar in History called "Mapping the Past," offered in spring semester 1999. Applying geographic visualization to history holds special challenges because of the long-standing, often extreme bias of historians favoring narrative and textual documents over visual forms of analysis and representation. This "logocentrism" – the privileging of words and logic over images and perceptual apprehension – makes history one of the least visual of the humanities.[6] It also means that many undergraduate history majors complete their studies with no exposure to maps and no training in geographic concepts or the responsible use of visual documents. If any discipline is ripe for evangelizing the revelatory power of geographic visualization, it is history.

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The substantive content of the course – the historical geography of New England and the region's cartogaphic history – was presented through traditional lectures, discussion, and student reports. The unifying concept of the course was that one can gain a rich and deep understanding of history by studying places as palimpsests of change, which geographic visualization can represent as serial images or layers that register change to a particular location. In applying geographic visualization to history, I stressed four points:

1. Both abstract ideas and empirical data can often be presented most effectively in graphic form, particularly when one wishes to convey spatial location, the simultaneity of events, or the complexity of conditions or relations that extend over geographical space.
2. Geographical concepts such as distance and proximity, density and dispersal, and human-environment relations are important factors to understand in any historical situation and are often best understood when visualized.
3. To glean the historical information contained in maps one must learn how to read and interpret them, taking into account cartographic conventions and the map's intended audience and purpose.

4. Maps and other visual elements are no more authoritative or final than any other part of an author's selective presentation of historical information.

We explored these concepts while working toward two pedagogical goals:

1. Cultivating the habit of asking geographical questions of history and using graphic sources and methods to answer them;
2. Providing principles and techniques of geographic visualization that students could apply in a final project and easily transfer to any other class.

Cultivating geographical habits of mind focused on the points summarized in Table 1: using maps to locate places, as sources of data, and as the means of representing intellectual models, a sense of scale, and historic context. This goal was in some ways the more difficult of the two. Although more than half of the eighteen students in the class expressed a life-long interest in maps and history, none had previously used maps to study history and only a few had ever made a map.

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The first step in developing new habits was to soften students' inhibitions about "being artists" and encourage them to experiment, to play with depicting historical ideas graphically. I began by trying to set an example, drawing on the blackboard at every opportunity, however bad the maps and diagrams.[7] As part of our discussion of William Cronon's regional history of Chicago, *Nature's Metropolis*,[8] students used historical maps of the city to find the location of districts and events that Cronon did not map and to discuss how the city has changed over the past 150 years. We examined Donald Meinig's cartographic diagrams of Turner's "frontier thesis."[9] In the third week I invited students to try their hand at sketching historical ideas, asking volunteers to draw graphic summaries of the social value of land among Native Americans and Puritans that Cronon presented textually in *Changes in the Land*.[10] The students' cartoon sketches prompted some laughter but also good discussion of complex social and spatial relations.

The first graded assignment, to critique an historical monograph, asked for a conventional analysis of the text plus comments on the author's use or neglect of cartographic and photographic sources. Having heard me criticize Cronon for including only a handful of maps in *Nature's Metropolis*,[11] the students felt free to venture their own criticisms of what was, in almost every case, historians' and historical geographers' omission and missed opportunity to visualize important aspects of their narrative histories.

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The second half of the course focused on the history of cartography in New England and how one can use maps as historical documents. The history of cartography section dealt mainly with J. Brian Harley's critical view of maps as socially constructed, historically embedded artifacts.[12] Some students were stymied by the complexity of the history of cartography, particularly the many variables one must examine to understand the historical context of a map's creation and use. But they were fascinated to learn that they could apply many of the same questions to maps that they were used to asking of written texts. The notion of invented traditions and how they were manifested and duplicated in maps made the deepest impression upon them.[13] This part of the course argued that no map should be used naively in research and that every map contains a wealth of historical meaning susceptible to extraction.

Purpose	Comment
1. Geographical orientation	Use maps to locate places, boundaries, and features of the natural or human landscape.
2. Sources of data	Maps can provide absolute and relative values; spatial patterns and relationships; data on the volume and direction of flows of people, resources, information; and qualitative impressions of place and space.
3. Models and arguments	Cartographic representations can be powerful means of presenting arguments about spatial relationships or models of complex systems, environmental or social. One can critique others' cartographic arguments by analyzing their content, representativeness, symbolization, and design.
4. A sense of scale	Maps can quickly convey the geographic extent of a social or natural phenomenon, its relative concentration or dispersal, and the changing significance of spatial variables from place to place.
5. Historic context	Maps from the study period can help you and the reader envision a time and place, though this must be done with care. They can also be analyzed as artifacts that embody cultural conventions, the state of scientific knowledge, and the attitudes of those who made them.
6. Presentation	Spatial data are often most effectively presented in map form. Maps can carry exceptionally high data densities while communicating meaning clearly and efficiently.*

*Edward Tufte, *The Visual Display of Quantitative Information* (Cheshire, Conn.: The Graphics Press, 1983), 161-169.

Table 1. Using Maps in Historical Research

MAPPING THE PAST

In their final research projects, students were to conduct research on the historical geography of a place or historical event of their choice. Each paper had to include at least one original map that expressed the central metaphor of the layering of the past by using at least two mylar layers, in registration or in sequence, to represent change over time.

I chose to teach the students how to make maps on mylar, using colored pencils and a light table, for several reasons. First, my experience teaching ArcView GIS at Wellesley had convinced me that the technology's learning curve was too steep to include it in a course whose primary respon-

sibility was to convey substantive content unrelated to GIS. Specifically, there was not enough time to teach the students enough GIS for them to use it in an independent project. Second, I expected that most of the source maps that students would be able to find in Wellesley's library would be paper rather than digital. Although growing numbers of historical maps and atlases are available on-line or on CD-rom, the great majority are still available only on paper.[14] I asked students to trace source material rather than scan it electronically to minimize differences between student projects and to give everyone the experience of duplicating and selecting spatial information by hand.

Third, mylar is cheap. With a $150 pedagogical grant from the College, I was able to purchase a pair of registration pins for each student and enough punched mylar to give each student five sheets, with extras for the ambitious. Students found their own colored pencils. They used a large light table in the Geology Department for compilation. This generated one of the unexpected benefits of using manual methods. Several students told me that this was the first time they had set foot in Wellesley's Science Center, a slightly forbidding place that they had assumed held no interest for them.

The final reasons for using manual methods were conceptual. Although maps in all media are made in layers, the physical separation of mylar sheets made the idea of history's layers concrete for students. The process of assigning different map elements and themes to individual mylar sheets reinforced the message that one must initially distinguish the various parts of the history of a place. Bringing them into registration powerfully made the point that places are complex, and that mapping spatial phenomena can reveal important, sometimes surprising juxtapositions. In their semester-end evaluations of the course and the project, almost all of the students said that the concept of layers had the greatest impact on their research and their view of history and place.[15]

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I taught two one-hour sessions on map-making techniques. These sessions were based on examples of historical map sources and discussion of the kind of thematic map that might be most appropriate for each student's project. Handouts told them how to make a graphic map plan, where to find cartographic sources, and how to cite them. I also demonstrated simple compilation techniques using base maps photocopied from sheet maps and historical atlases. I dismissed the issue of geodetic accuracy as too fine a point to worry about in this context, though I did emphasize the significance of knowing which map projections were used for small-scale base maps.

The final papers examined a wide range of topics that reflected students' diverse academic interests. Some students chose subjects that they had already studied in a history class but wished to look at from a fresh point of view. The most striking of these was a paper by Rebecca Harvell, a graduating history major who had previously written many papers on Native Americans but had never mapped the territories native peoples inhabited or where they were forced to relocate. Her cartographic reconstruction of the U.S. government's redefinition of the Sioux Reservation in 1851-1889, drawn largely from government documents, more than illustrated her paper. Nearly half of the paper directly addressed the four maps, which depicted the culmination of each distinct phase of government policy toward the Sioux (see Figure 1).[16] Making the maps, Rebecca told me, brought home the drama of federal and business interests' depredation of Sioux lands. The geographical narrative of the reservation's shrinking boundary encapsulated a complex story of conquest and defeat.

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Another history major, Rachel Hirsch, used the mapping of historical narrative and events to analyze military strategy. By mapping the geog-

Figure 1. ***Containing the Sioux, 1851-1889****. This series of maps by Wellesley College student Rebecca Harvell shows the shrinking domain of the Sioux people as the U.S. government established military control over former Sioux territory and secured mineral lands for private exploitation.*

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raphy in Xenophon's *Anabasis* alongside a map of Alexander the Great's military compaigns, she determined that the historian's geographic descriptions had influenced Alexander's strategy. Visualization enabled her to compare military routes and the sequence of events simultaneously. It also helped her imagine the physical topography and the difficulties it posed for Alexander and his opponents. The course convinced her to use methods of geographic visualization in her own teaching of history at a local high school.[17]

Some students found geographic visualization helpful in integrating information from various sources or discovering patterns within complex data. The former made mapping essential in psychology major Lindsey Clark's study of the relationships between Icelandic culture and the island's active geology. Linnea Noreen mapped population distribution against the historic development of parks and train lines in turn-of-the-century Seattle to analyze the forces driving urban planning in her home town. Sophie Parker, a biological sciences major taking her first history class, was overwhelmed by the volume of material she found on the construction of the Los Angeles aqueduct until she mapped it. She told me that seeing the aqueduct in its relation to Owens Valley farms and the subsequent explosion of Los Angeles' territorial extent snapped the story together.[18]

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For other students, mapping landscape provided a means of examining more abstract and emotional perceptions of place. Anne Petz found that

mapping the development of nineteenth-century tourism in Yellowstone National Park helped her understand the park's social construction as a tourist destination. It also helped structure her own fond recollections of time she spent in the park. Elizabeth Repass, a first-year student who is now pursuing an independent major in geography, used the process of mapping perceptions of eastern Washington state to test her own regional prejudices as a native of Seattle.[19]

Maps also proved to be important sources for several papers. Large-scale historical maps and photographs gave Margie Schnitzer her best material on the poorly documented saltworks of nineteenth-century Cape Cod and their relation to maritime industries and coastal tourism. Lia Shimada's study of physical bases for the mythical island identity of Glastonbury relied on British Ordnance Survey topographical maps and archaeological renderings of the site.[20]

The most striking case of maps revealing crucial historical information came in the research of Amy Beltz, a senior majoring in history and Spanish. She was intrigued by comments a family friend had made about Oak Ridge, Tennessee, which gave her the impression that Oak Ridge and other nuclear reservations were strange and fearful places. Encouraged to explore this geographic concept, she researched the construction, population, nuclear production, social life, and journalistic representation of Oak Ridge, with comparisons to the Hanford nuclear reservation in Washington state. The turning point in her research came when she examined U.S.G.S. topographic quadrangles of the Oak Ridge and Hanford sites at various dates. The maps of Oak Ridge convinced her that reports that residents of Oak Ridge knew very little about the nuclear installations where they worked were probably true, given how well the facilities were hidden among the deep folds of the Appalachians. The maps also helped her understand the scale and geographical expression of the town's racial and social divides. Amy's greatest discovery, however, came when she compared Hanford quadrangles from the 1950s and 1960s to more recent maps. The earlier maps showed roads and railroads terminating abruptly where she knew nuclear facilities had been built. She had found stunning cartographic evidence of Hanford's top-secret status. Everything the maps revealed, Amy wrote in her evaluation of the project, was "essential to visualize, to understand, life with the bomb."[21]

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Nina Davis, a senior in Peace and Justice Studies with no prior background in history, was the one student to make maps from both archival records and field notes. For her study of the changing functions of Quincy Market, built on Boston's waterfront in 1824, she mapped the stall locations of Market vendors in 1867, based on detailed listings in the Boston city directory of that year. She then conducted a field survey of the Market's present-day retailers (see Figure 2). Because the footprint of the Market had not changed between 1867 and 1999, she was able to make a direct comparison of the Market's occupants and functions at two distant points in time. Nina's analysis of the site's historical uses was richly specific, illuminating changes in transport and trade and the social character of Quincy Market and its neighborhood. "Making the maps, plotting data, and then studying and comparing maps was a tool in my thought and writing process," she wrote in her survey reply. She felt that making maps "complicated" her view of history, which I found particularly heartening.[22]

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In most of the papers, geographic visualization was central to the conception of the study and to its presentation. I was struck by how many of the students' findings were based on geographical data and how well they integrated graphic and textual analysis. Most of the final projects showed that students had learned basic principles of geographic visualization

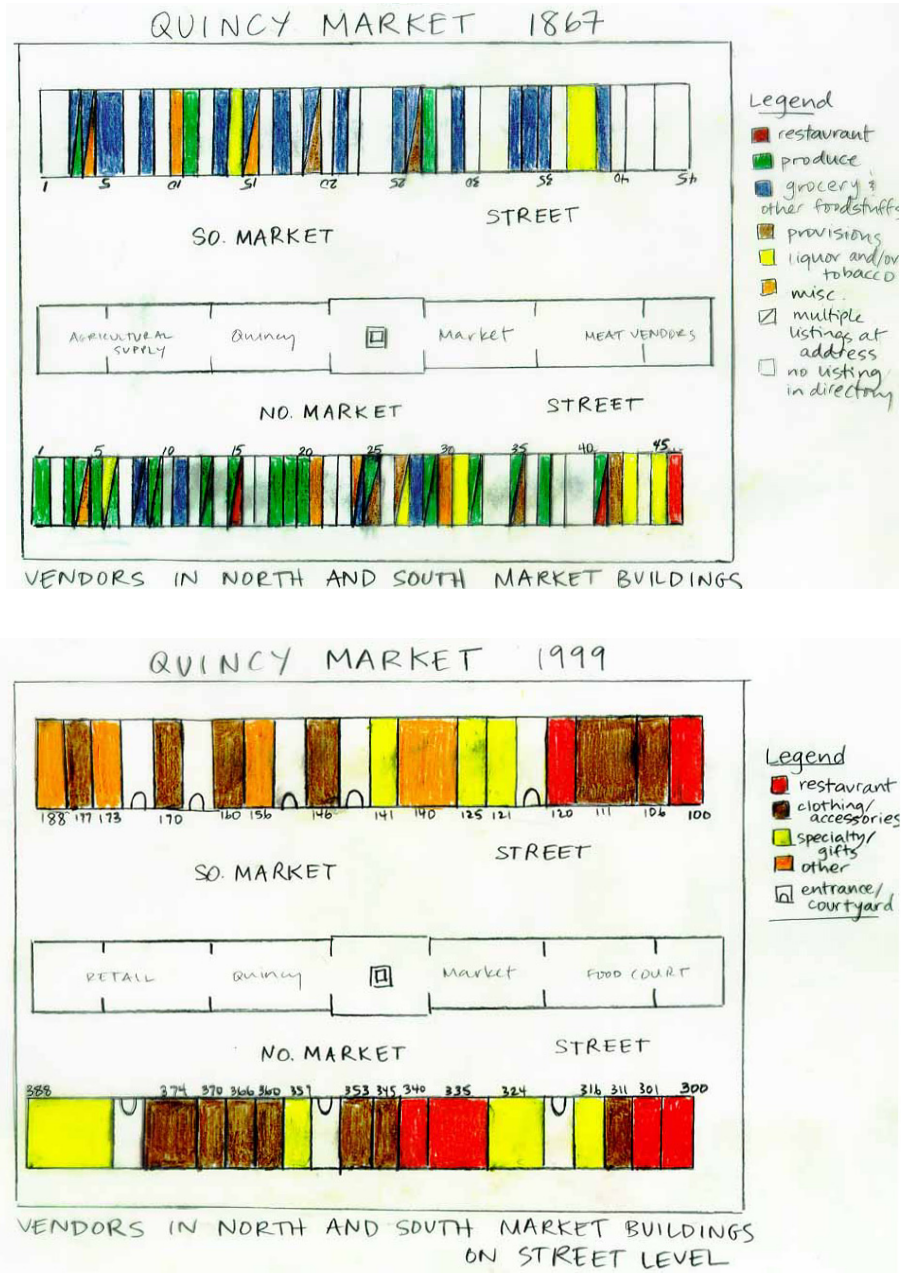

Figure 2. ***Changing Functions of Quincy Market, 1867 and 1999****. Wellesley student Nina Davis found that mid-nineteenth-century retailers in Boston's Quincy Market supplied the daily needs of city residents and the maritime industry. At the end of the twentieth century, the renovated Market's retailers catered to the tourist trade.*

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and applied them creatively in an historical context. None had previously used or made maps as part of their college coursework, except for a few students who had studied geological maps in geology courses. All but one of the students who responded to a post-semester survey said the two short map-making sessions had provided adequate instruction, which the projects confirmed. More importantly, most students had learned a great deal about their study area through the process of creating their mylar compilations.

CONCLUSIONS

New paradigms and technological change tend to create advocates for the new and defenders of the old. In the now well-established GIS/geo-visualization revolution that is changing the practice and the very meaning

of cartography, defenders of the old ways of making maps have been few and for the most part half-hearted. Teaching and scholarship in what used to be known as cartography is overwhelmingly being devoted to developing computer-enabled geographic visualization and to training a new generation of investigators to work in virtual environments.

I came to Wellesley College seeing myself as part of the vanguard. I was eager to impart GIS technology to students and to help the College incorporate GIS and geography into its curriculum for the long term.[23] The rude awakening of struggling to teach GIS without recourse to a well-equipped geography department forced me to think hard about how students could benefit most from a brief encounter with geographic visualization. Experience led me to conclude that many of the fundamental concepts that make geographic visualization so exciting can and perhaps should be taught with manual methods. Manual methods can be far less tedious than GIS; they can be used to interrogate many kinds of data, provided the data load is not too heavy; and they can be treated experimentally if one teaches map-making as a process of "graphic ideation" and information design rather than as a method of formal presentation.[24] Manual methods need not be limited to producing "single more-or-less optimal" maps, as recent criticism has implied.[25] Training in the most elementary draftsmanship can in fact facilitate visual brainstorming, doing "quick freehand drawings [that] may be created as part of the evolving enquiry for personal consumption."[26] Drawing from observation used to be part of the basic training of geographers and cartographers. That kind of visualization, a deeply creative act, is as old as Galileo's small sketches of the changing positions of Jupiter's moons.[27] Once learned, it is an easy, inexpensive, extremely portable method for visualizing spatial data and geographical ideas.

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One of the models for introductory geotechniques courses is David DiBiase's course, "Mapping Our Changing World" at the Pennsylvania State University.[28] DiBiase puts visualization at the heart of geographic education but draws back from teaching GIS at the introductory level. He argues that students need to master the conceptual content of geographic information, and understand the social contexts in which it is produced and consumed, before they learn a complex proprietary GIS package. DiBiase also sees a vast untapped market for introductory courses in geographic information that can satisfy the growing demand for "information literacy," particularly if they can avoid the logistical and financial problems of large computer-workstation laboratories.[29] While I agree with many aspects of his approach, I believe its emphasis on obtaining and manupulating geographic information via computer comes at the cost of instilling principles of graphicacy and critical thinking about graphic communication.

The students in my history class convinced me that geographic visualization is a tremendously powerful tool for studying the past.[30] Their excitment at encountering a genuinely different way of seeing the world – new because it called upon them to apply critical reasoning to what they see – renewed my conviction that a geographical perspective can invigorate any branch of learning. Manual methods make the revelation available to students in any discipline at any educational institution. Simple map-making and graphic ideation are exploratory tools that quickly get students thinking geographically and enable them to engage with many sources of spatial data. While these methods cannot manage the chaos of large computerized data sets, they do clearly convey the principles that geographic visualization can raise questions, reveal patterns and relationships, and communicate meaning.

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1. John B. Krygier, "Envisioning the American West: Maps, the Representational Barrage of 19th Century Expedition Reports, and the Production of Scientific Knowledge," *Cartography and Geographic Information Systems* 24, no. 1 (1997), 28; Krygier, "Visualization, Geography, and Landscape: Visual Methods and the Study of Landscape Dereliction as a Process," Ph.D. diss. (The Pennsylvania State University, 1995). As Krygier points out, geographers of the critical school consider the visual emphasis of geography one of its great weaknesses and intellectual problems; for example, see, inter alia, Denis Cosgrove, *Social Formation and Symbolic Landscape* (Totowa, N.J.: Barnes and Noble, 1984); Derek Gregory, *Geographical Imaginations* (Cambridge: Blackwell, 1994); and the striking lack of visualization of any kind in the work of David Harvey.

2. Alan MacEachren and Mark Monmonier, "Introduction," in *Cartography and Geographic Information Systems* 19, no. 4 (1992), 197-200, quotation on p. 197. See also M. Visvalingam, "Visualisation in GIS, Cartography, and ViSC," in *Visualization in Geographic Information Systems*, edited by Hilary M. Hearnshaw and David J. Unwin (Chichester: John Wiley & Sons, 1994), 18-25 and Krygier, "Visualization," pp. 6-7. The best textbook representation of the paradigm shift is Terry A. Slocum, *Thematic Cartography and Visualization* (Upper Saddle River, N.J.: Prentice Hall, 1999).

3. Wellesley College Archives, Minutes of Academic Council, pp. 321, 390; Records of the Dean of the College, Academic Departments, Geology Department, Annual Report for 1964-1965 by Prof. Eiselen [geography], June 7, 1965. Joni Seager, now Professor of Geography at University of Vermont, taught a course on feminism and the environment in Wellesley's Women's Studies program in 1991. She was also a Fellow at the College's Women's Studies Center in 1984-1985. My two-year postdoctoral Mellon Fellowship, which ran from July 1997 to July 1999, was sponsored by three social science departments and informally involved several others.

4. Environmental Systems Research Institute, *Getting to Know ArcView GIS: The Geographic Information System (GIS) for Everyone* (Cambridge: GeoInformation International, 1997).

5. David DiBiase, "Rethinking Laboratory Education for an Introductory Course on Geographic Information," *Cartographica* 33, no. 4 (Winter 1996): 65.

6. Barbara Maria Stafford, "The Visualization of Knowledge from the Enlightenment to Postmodernism," in *Good Looking: Essays on the Virtues of Images* (Cambridge, Mass.: MIT Press, 1997), pp. 20-40. Evelyn Edson dates historians' ignorance of maps to the thirteenth century, when, she finds, very few historians "created and used maps as an adjunct to the writing of history . . . Some of the greatest historians of the Middle Ages . . . come

to us usually unillustrated and always mapless." *Mapping Time and Space: How Medieval Mapmakers Viewed Their World* (London: The British Library, 1997), 132.

7. Geographer Harm de Blij gave a marvellous demonstration of almost comically bad but conceptually brilliant geographic sketching during his keynote address to the New England Mapping Organization at Wellesley College, June 3, 1999. In half a dozen black-marker maps, drawn with apologetic haste on a flip chart, he rendered the maps that were milestones in his personal geographical awareness, including the wall map in his home in Holland on which his father plotted the advance and retreat of the Allies during World War II.

8. William Cronon, *Nature's Metropolis*: *Chicago and the Great West* (New York: Norton, 1991).

9. Donald W. Meinig, *The Shaping of America: A Geographical Perspective on 500 Years of History*, vol. 2, *Continental America, 1800-1867* (New Haven: Yale University Press, 1993), pp. 260-261.

10. William Cronon, *Changes in the Land: Indians, Colonists, and the Ecology of New England* (New York: Hill and Wang, 1983).

11. Cronon, now Frederick Jackson Turner Professor of History, Geography, and Environmental Studies at the University of Wisconsin-Madison, has engaged a cartographer to assist with his latest project, a history of Portage, Wisconsin and the great environmental thinkers associated with the town. Maps are playing an important part in his research for the project. Personal communication, Wellesley College, February 19, 1999.

12. J. Brian Harley, "Texts and Contexts in the Interpretation of Early Maps," introduction to *From Sea Charts to Satellite Images: Interpreting American History through Maps* (Chicago: University of Chicago Press, 1990), pp. 3-15; Harley, "Deconstructing the Map," *Cartographica* 26, no. 2 (1989), pp. 1-20; Matthew H. Edney, "Cartography without Progress: Reinterpreting the Nature and Historical Development of Mapmaking," *Cartographica* 30, nos. 2 & 3 (1993), pp. 54-68.

13. Martyn J. Bowden, "The Invention of American Tradition," *Journal of Historical Geography* 18 (1992), pp. 3-26; Eric Hobsbawm, "Introduction: Inventing Traditions," in *The Invention of Tradition*, edited by Eric Hobsbawm and Terence Ranger (Cambridge: Cambridge University Press, 1983), pp. 1-14; Martyn Bowden, lecture on the invention of New England, Wellesley College, February 22, 1999.

14. Interview with David Cobb, Director, Harvard Map Collection, Harvard University, Cambridge, Mass., July 21, 1999.

15. Student evaluation questionnaires for History 369, May 1999; survey of students by mail, June-August 1999, to which eleven of eighteen course members replied.

16. Rebecca Harvell, "The Reduction of the Sioux Reservation from 1851 until 1889," final paper, History 369, Wellesley College, May 1999.

17. Rachel Hirsch, "Geography as the Catalyst for Military Problem Solv-

ing: An Examination of Xenophon and Alexander," final paper, History 369, Wellesley College, May 1999; personal communications, August 4, 1999 and April 14, 2000.

18. Lindsey Clark, "Fire and Ice: Geology in the Layers of Icelandic Culture"; Linnea Noreen, "Seattle: The City on a Hill"; Sophie Parker, "Urban Water Imperialism in Turn of the Century Los Angeles: The Conception and Creation of the Los Angeles Aqueduct." Final papers, History 369, Wellesley College, May 1999; Sophie Parker, personal communication, May 8, 1999.

19. Anne Petz, "Yellowstone National Park: The Formation of a Place in American Culture"; Elizabeth Repass, "The Space Is Huge and Empty." Final papers, History 369, Wellesley College, May 1999.

20. Margie Schnitzer, "The Nineteenth Century Saltworks of Cape Cod"; Lia Shimada, "Glastonbury: England's Invisible Island." Final papers, History 369, Wellesley College, May 1999.

21. Amy Beltz, "A Landscape of Fear: Oak Ridge, Tennessee," final paper, History 369, Wellesley College, May 1999; signed form, "Survey of Students in History 369," received July 18, 1999.

22. Nina Davis, "Boston's Quincy Market: Changes in Function and Meaning, 1826-Present," final paper, History 369, Wellesley College, May 1999; signed form, "Survey of Students in History 369," received July 20, 1999.

23. Some members of the administration and faculty of Wellesley College remain interested in reinstating geography and in teaching GIS, but constraints on faculty hiring have put the idea indefinitely on hold.

24. Michael Wood, "The Traditional Map as a Visualization Technique," in *Visualization in Geographic Information Systems*, p. 14. Edward R. Tufte remains the American master of information design, although he has given little critical attention to the design of geographic information. See Tufte, *The Visual Display of Quantitative Information* (1983); *Envisioning Information* (1990); and *Visual Explanations: Images and Quantities, Evidence and Narrative* (1997), all from Graphics Press, Cheshire, Conn.

25. Alan M. MacEachren and Mark Monmonier, "Introduction," pp. 197, 198. See also Alan M. MacEachren, "Visualization in Modern Cartography: Setting the Agenda," in MacEachren and D. R. Fraser Taylor, eds., *Visualization in Modern Cartography* (Oxford: Pergammon Press, 1994), pp. 1-12. Similar views dominate the geographic visualization literature.

26. Wood, "Traditional Map," p. 14.

27. Peter Haggett, *The Geographer's Art* (Cambridge: Blackwell, 1990); Edward Tufte, *Envisioning Information* (Cheshire, Conn.: Graphics Press, 1990), pp. 96-98.

Erwin Raisz was a compulsive drawer, filling scores of notebooks with graphic observations and plans for cartographic productions. He was also an intensely visual teacher, from training students to be draughtsmen in his introductory geography course to drawing longitudinal cross-sections of regional landscapes, freehand, on long rolls of art paper by way

of outlining his lectures -- and requiring students to take graphic notes. "One Hundred Years of Art and Science in Cartography: An Exhibit of Manuscript Drawings, Maps, Journals, and Publications of Erwin Raisz, Harvard's Most Prominent Mapmaker," at Harvard Map Collection, Harvard University, January-July 1999; Erwin Raisz, *General Cartography* (New York: McGraw-Hill, 1948), esp. chaps. 4 and 5; Joseph Garver, "Plainly Visible Patterns," *Mercator's World* 4, no. 5 (1999), pp. 32-39; Phillip Muehrcke, "Maps in Cartography," *Cartographica* 18, no. 2 (1981), pp. 1-41.

28. Web site for the course on the Internet at http://www.gis.psu.edu/geog121/home.html, accessed 17 May 2000.

29. DiBiase, "Rethinking Laboratory Education," p. 62. DiBiase presented the promising results of the first course in his on-line GIS certificate course (a module based on his classroom teaching of a conceptual introduction to geographic information) in "Customizing GIS Software for Distance Learning," annual meeting of the Association of American Geographers, Honolulu, Hawai'i, March 26, 1999.

30. Cartographer Keith Clarke and classics scholar Adele Haft drew similar conclusions from teaching a course at Hunter College that combined training in cartography and lectures on the intellectual history of cartography with analysis of the geography embedded in works of literature. Telephone interview with Keith Clarke, University of California-Santa Barbara, May 16-17, 2000.