Picturing college access providers in Virginia: Navigating the methodological and epistemological challenges of GIS mapping

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ABSTRACT

Geographic Information Systems (GIS) mapping has emerged as a popular method to convey complex social, demographic, and geographic data in such fields as education, law, and the social and physical sciences. However, researchers, practitioners, and policymakers may not be aware of or sensitive to the complex issues of power, exclusion, meaning-making, and agenda-setting embedded in an apparently self-evident visual representation format. Nor are they likely to be aware of the ongoing debate between cartographers and GIS technicians over the responsibility of map makers to anticipate and address social and ethical issues related to data representation. This paper is based on the authors' process of encountering, employing, and reflecting upon GIS mapping during a state-wide project examining the distribution, activities, and target populations of college access provider organizations. Categories of logistical, representational, and interpretational issues arose, requiring the researchers to consider how their mapping efforts might be used in an educational policy arena to misrepresent, oversimplify, or exclude some constituents from policy formation and resource allocation processes. In turn, educational researchers considering GIS mapping are challenged to do so fully aware of the methodological and epistemological challenges of the process.

Keywords: GIS, mapping, representation, access, ethics

INTRODUCTION

Creating actionable policy recommendations is often a matter of data representation, in addition to data collection and analysis. However, just like collection and analysis, representation may also be laced with meaning-making expectations and imbued with assumptions of which groups ought to have access to the tools of policy formation. This paper explores the implications and challenges of one particular data representation approach: Geographic Information Systems (GIS) mapping. GIS is "a computer system capable of capturing, storing, analyzing, and displaying geographically referenced information; that is, data identified according to location. Practitioners also define a GIS as including the procedures, operating personnel, and spatial data that go into the system" (USGS Website, 2007, para 2).

Based on a federal College Access Challenge Grant and administrated by the State Council of Higher Education for Virginia (SCHEV), the larger study from which this analysis emerged examined college access provider organizations in the Commonwealth of Virginia. College access providers are non-profit groups that promote college-going among academically at-risk K-12 students who lack the skills, information, and aspirations necessary to apply for and enter higher education. That study sought to identify the type and distribution of college access provider organizations, as well as the resources and activities they offered to students in their service areas. Although prior studies (most significantly Gandara & Bial, 2001; Gullatt & Jan, 2003: Perna, 2002; Perna & Swail, 2001) have offered valuable nationally-generalized descriptions, analyses, and typologies of such programs, this is the first study to pursue a comprehensive, state-level analysis upon which policy recommendations can be built. GIS mapping offered an easily accessible method for showcasing areas of college access need and success that correlate with past related policy initiatives, and to show areas of need for future policy action.

Virginia is a state of 132, K-12 school divisions, each facing unique demographic and achievement obstacles using a unique set of resources. The challenge of this study was to translate large amounts of school demographic and achievement data, along with college access provider data, into a format that was both accessible and descriptive. Adding to this challenge, the mandate for this study included a directive that findings be distributed to a wide range of constituents, including educators at all educational levels, college access provider administrators, and policymakers, which included state and local public officials.

The variety of constituents targeted by this study emerged as a complicating issue as we considered using GIS mapping to represent our data. Data consumers often lend greater legitimacy to maps and other visual data representations as self-evident data points. Consumers are also less apt to recognize the socially-constructed nature of mapping and may fail to subject it to the same critique as other policy data (Monmonier, 1991). Furthermore, the visual simplicity and approachability of many maps belie the often complex processes of data collection and interpretation from which the maps emerged. Mapping, according to some critics (Taylor, 1990) thus represents a new sort of scientific empiricism; a complex and biased argument cloaked in the apparent conceptual clarity of a visual fact. As noted by Schuurman (2000), GIS is not the first type of mapping to receive this critique. However, the application of GIS to a wide variety of fields and disciplines such as the health sciences, education, and ecological research that are often linked to policy decision-making, and questions about who has access to this powerful technology have renewed concerns about responsible use.

This paper explores and analyzes GIS mapping from the perspective of educational researchers employing GIS as a tool to further policy development at the state level. Yet, embedded in GIS use were issues concerning the inherent power of the researchers, the logistical manipulation of data, and the representational outcomes of the process. Some elements of this conversation reflect aspects of an ongoing dialogue and controversy in the cartography and geography fields (Shuurman, 2000; Sieber, 2006), and other elements represent broader data representation issues that arose in the context of our study. This ongoing conversation, in the context of educational research, presses practitioners and researchers to reflect on the hazards and opportunities of graphically representing data generally, and use of GIS mapping specifically.

GIS MAPPING: OPPORTUNITIES AND COMPLICATIONS

We came to use GIS mapping through a process of exploration and modification. Early in the project we recognized that displaying the distribution of access providers visually would simplify our efforts to convey complex state-level data. After exploring several less technologically sophisticated systems (such as the use of paper maps and online Google Maps), we connected with a faculty member at our institution's geography department, who was at that time creating GIS-based maps of community colleges and local demographics for a colleague. Our initial meetings with the faculty member challenged our neophyte understanding of the GIS mapping process, and we became increasingly aware of the amount of time necessary to prepare our data to be compatible with the GIS software. Complications quickly multiplied. Although our initial hope had been to connect our findings to individual high schools, the smallest available geographic unit of analysis was an existing division-level GIS data set. Although the research team provided the data, the geographer and his assistant advised our process, including best approaches to representing data, processes for converting data to mesh with the GIS software, and the layout of the mapping products (see Appendix 1: College access provider distribution map (color coded 1-13 by density) with regional demarcations).

Visually representing data through GIS mapping is an issue that has received increased scrutiny and attention over the past two decades, largely dividing technicians who view GIS capabilities as a credible and descriptive tool, from geography theorists who tend to critique GIS mapping as a new tool of positivism, and therefore imbued with false assumptions of value-neutrality and subject-object disconnection (Aitken & Michal, 1995; Pickles, 1995; Shuurman, 2000). Geographers have noted the particular power of maps generally as a persuasive and seemingly irrefutable self-evident fact (Monmonier, 1991). According to Obermeyer (1998), the issue at stake contains important practical policy implications:

> The use of geographic information systems can make it increasingly difficult for average citizens to participate in ongoing policy debates. This difficulty arises because using GIS simplifies the performance of spatial analysis and the preparation of excellent graphics (maps being the most obvious example), which lend an aura of persuasiveness to the reports on policy that public and private institutions prepare. No matter how sound (or unsound) the underlying ideas, the GIS can make a report seem more authentic and authoritative than it otherwise might seem. (p. 2)

These critical and theoretical perspectives on mapping are often grouped under the moniker GIS Society, or "GISoc". Many GISoc theorists view mapping as a socially-constructed phenomenon that is subject to the same bias, access and exclusion issues, and majority group dominance that has plagued other forms of inquiry and expression historically

(Shepherd, 1995). Given this critique, the question arises: can GIS mapping be wrested from the exclusive control of academic, governmental, and private sector interests, and used to empower and equip these same individuals and groups who are frequently excluded from policy decision-making?

To some researchers, the answer is a qualified "yes" (Ghose, 2001; MacEachren, 2000). Under the banner of Public Participation GIS, or "PPGIS," researchers and activists create user-friendly tools, hold seminars, and engage in community organizing that promotes access to GIS tools as a means of local participation in public policy and decision-making. Those engaged in PPGIS have found, however, that although mapping can be an avenue for indigenous and underrepresented groups to advance their interests, circumstances such as limited access to databases, limited technical expertise, group turnover, and unforeseen or undesirable responses to mapping sometimes frustrate such efforts (Sieber, 2006).

Access to mapping is complicated by the tools and knowledge needed to harness them, ranging from the simple to the sophisticated. Popular free internet programs, such as Google Earth, are based on the GIS platform and are designed for users to work on small projects using the provided, but limited, maps. Professional GIS programs, such as ArcGIS, cost thousands of dollars for a license and require specific training to use. Not only do GIS professionals need to understand what types of maps and data are already available for use (for instance, school division maps in Virginia were already available and did not need to be developed for the project), but users also need advanced knowledge in the use of databases and data entry software in order to construct new maps, layers, and integrate data from secondary sources.

Researchers note that the increasing use of GIS mapping for education, health-care, and public policy argument-making represents a potent resource for delivering compelling data that must be used conscientiously and judiciously (Haque, 2001; Kwaku Kyem, 2004). However, as interest in GIS mapping has increased, it draws increased attention from diverse disciplines, fields, and interest groups. These newly involved parties, often not privy to insider conversations about mapping access, ethics, and representation, are discovering the opportunities and hazards of this work on their own. Like many researchers, we initially engaged in mapping strictly as a representational tool, working cooperatively but dependently with a professional geographer. In retrospect, we now understand that through the process of map development we occupied the positions of power majority (to the school divisions and access provider organizations we sought to describe) and advocating minority (to SCHEV and other governmental agencies we sought to convince) simultaneously. Finding a balance between these positions of power was an unforeseen challenge that led to an ongoing conversation about the influence of mapping and its impact on our overall study.

MAPPING PROCESSES AND CHALLENGES

In this paper we explore three methodological and epistemological challenge areas: *logistical issues* (the basic mapping challenges we initially faced that led to GIS map use); *representational issues* (the difficulties we experienced as we compiled and interpreted complex data from which the maps were derived); and *interpretational issues* (our political and symbolic concerns about the ways constituents might misapply or misconstrue the maps). More than an ancillary aspect of the study, mapping methodology was intertwined with the logistical and representational challenges of this project in general. Consequently, the methodology of map designing will be treated as both process and result in our analysis.

Logistical Issues

Although college access organizations are a familiar research topic (Gandara & Bail, 2001; Gullatt & Jan, 2003; Perna, 2002; Perna & Swail, 2001; Tierney & Jun, 2001), our novel state-level analysis approach meant we could not benefit from existing models to help us design a data-gathering process, or to anticipate constituent and political obstacles during the research and reporting stages. Our research team identified college access provider organizations in Virginia through state and non-profit databases, as well as a snowball technique through an online survey. From this initiative we identified 480 access provider instances[1] spread over 132 school divisions.

The two central logistical challenges posed by GIS mapping dealt with managing the strategic advantages and disadvantages of this process. The first logistical challenge we faced was determining the unit of analysis. Although the access provider data we had gathered would serve as the basis for the maps, conceptualizing the unit of analysis was problematic. The access providers' administrative locations and mailing addresses often did not correspond with the site of services. For parents, students, and educators, the distribution of service sites was the issue of interest. Developing maps based on provider mailing addresses or home offices would be technically accurate, but functionally of little use. Thus, the schools themselves as the site of most service interventions (providers typically bring services to those served), and not the access provider's office locations, became our mapping focal point. However, this decision led a subsequent logistical challenge.

The second logistical challenge arose from the databases used to construct provider maps. Generally, the geographic and demographic data available is constrained by the scope of the most basic unit of analysis. In our case, describing the distribution of providers at the school level would have yielded the most precise maps, but this approach faced two impediments: first, because of the sheer volume of data, we would be confined to a set of regional maps and would not be able to display a state-level map with the detail desired. Second, and even more important, at that time, no school-level GIS maps existed that would allow us to identify the geographic boundaries of each unit. Although several national mapping initiatives are underway, high schools in Virginia, as in most states, operate on a feeder system from elementary schools to middle schools, and on to high schools. As a result, although paper maps may exist in division offices, there were no state-level digital maps of the boundaries of individual schools. The smallest unit of analysis available was the school division, or clusters of school districts, most often defined by county or city borders.

Representational Issues

These logistical issues are easily overlooked as the trifling obstacles that are part of any research project. However, limitations inherent to translating social data into geographic data forced us to conform our ideas of data representation to those best suited for the maps. In essence, map-making shifted from a resource to a process driver, determining our unit of analysis and forcing us to reconfigure data to match the input needs of the software. Despite these

[1] The term "instances" is used since many providers operate as semi-autonomous branches of or as members within a larger organizational network. Since the number of networks is less important than the specific locations they serve, we elected to base our count on areas served by distinct entities of service to increase descriptive power.

encumbrances, our increased investment in the mapping process revealed three additional representational issues that helpfully challenged us to consider the most useful form and delivery of data to constituents.

The school boundary problem created our first representational issue. Identifying access providers by school district reduced the descriptive accuracy of our findings, since the number of schools contained in one division varies by local population, history, and other factors. For example, both Fairfax County and Alexandria City Public Schools have eight college access providers (non-profit organizations, public agencies, or higher education institutions) operating within their divisions. However, Alexandria City includes one public high school while Fairfax County Schools includes 26 public high schools. On a provider distribution density map, the two divisions appear to be equally serviced, yet students in Alexandria City have access to the full compliment of access services described by the provider count, while students in Fairfax County may not, since that same number of providers is unequally distributed among a large number of schools. To parents or students, the map misleadingly appears to indicate equal services among these two school districts, as it would be to a local philanthropic organization interested in supporting or initiating an access provider organization. Thus, although to say both districts have eight providers is correct, the availability of access services or the urgency for the development of new services has been inaccurately represented. And although the original study included figures that described and illustrated these differences, the translation to and accessibility of mapping may reduce the likelihood that study consumers will invest the time necessary to understand these crucial nuances by reading the complete study.

A second representational issue dealt with the varied types of access organizations that constituted the provider count for any given school division. Our total count included all public and private not-for-profit college access providers whose primary purpose fit the following definition developed from our data collection and analysis: any organization through which an individual gains the knowledge, skills, or support necessary for college aspiration, qualification, application, and enrollment (based on Cabrera & La Nasa, 2001). To qualify as an access provider in Virginia, an organization must have staff physically working within the Commonwealth and thus, within a school division. However, the services, resources, and organizational missions of these varied groups, in aggregate, resulted in combinations that may or may not meet the needs of local constituents. For example, both Henrico County Schools and Prince Edward County Schools had five "college access providers" working in their respective districts. Four of the providers in Henrico County were traditional community-based private organizations working within the schools, and the fifth was a community college-based Career Coach operating in a similar manner. By contrast, Prince Edward County Schools had one traditional access provider organization, a Career Coach location, a federally-funded GEAR UP location, and two colleges or universities (one public, one private) which were also included in the access provider count. Thus, the density and distribution map fails to capture the important distinction between types of provider organizations, with significant implications for the types of services that may be available.

In our data analysis process we were challenged by a state policymaker who, upon reading a draft of our study, asked what the provider count really indicated to readers of the study. To accurately represent the type of organizations, we constructed a table with nine categories of providers (including private, locally-based organizations, state-funded initiatives, federally-funded initiatives, and the aforementioned degree-granting two or four-year colleges and universities) listed by school division. One might imagine that adding additional map layers

illustrating population and provider type could easily alleviate these representational challenges. Yet, adding these layers resulted in maps that were too crowded and difficult for constituents to understand, highlighting the tension between representation and accessibility.

Thus, although revealing the layers of variation that were part of the provider count became an interpretational issue, it was first a representational one: despite the fact that the table clarified the nature of the accumulated count by school division, we found no way to reflect that detail through GIS maps[2]. In summary, although the mapping project faced a variety of representational issues, perhaps the most important was the combined effect of the dissimilar school division sizes and the disparate types and missions of the access provider organizations. The maps, though visually impressive, cloak the complexity of these two factors in the deceptively simple and self-explanatory guise of a single access provider count data point.

Interpretational Issues

The representational issues establish the context for and content of issues of sense-making among constituents of this study, raising several questions about the role of the authors in developing and disseminating the findings of the report. First, we questioned what sense various constituents and stakeholders would make of the provider density maps, and our responsibility in that meaning-making process. At the state level, we were subtly encouraged not to report our findings in a way that cast the ongoing college access initiatives of the Commonwealth in a particularly negative light. In this regard, the map data cut both ways, reflecting the increased resources SCHEV and other agencies had targeted toward particular regions, but also (in conjunction with demographic and achievement data) highlighting areas of acute need with little or no state response. We were deliberate in our efforts to link the maps to data and discussions of the complexity of the access provider environment. However, we quickly realized that despite our role as authors and designers of the study, once this product entered the public arena we were no longer in control of the interpretation process or product.

Realizing our limited control over constituent interpretations and use of the maps raised a second set of questions that were complicated by a growing level of interest by SCHEV, legislators, and other stakeholders as they learned that these maps were under development. At the state and local level we were concerned that provider distribution data would be interpreted apart from important demographic, population density, and achievement data. We wondered: would state legislators, each of whom also received a SCHEV-designed and distributed four-color brochure prominently featuring the density map, use it alternatively as evidence of a rampant problem or as the absence of a college access problem in their district or in the state in general? Would college access providers interpret the maps (and hence, our study) as championing their work and as evidence for additional support, or as misconstruing and under-representing the effect size of their efforts? Would local school officials receive this data as indicative of significant needs and seek out cooperative relationships with access providers, or view it as an unwelcome public indictment of their schools? Although we share the concerns of writers critical of GIS mapping for its empiricist roots and apparent value-neutrality (Lake, 1993), the above questions also highlight that meaning emerges through discursive communities

[2] Although constructing web-based interactive maps may have provided more options for representation, this approach would also have limited opportunities for display and presentation. Ultimately, SCHEV elected to use the data from this study and construct those very maps as a tool for parents, educators, and policymakers. The maps are available through their website: www.SCHEV.edu.

and the interchange of language within them (Gergen, 1992), beyond the control of those who originate the subject matter. As a result, our role in setting the agenda through the map creation was only one element in the continuous meaning-construction of a variety of overlapping political, social, and educational communities. These communities are neither (or not simply) hapless victims of map data, nor are they immune to the possibly disruptive or persuasive influence that the maps may levy. Nevertheless, we also acknowledged our responsibility to be actively engaged in this public conversation, and to hear the interpretations and concerns of state and local constituents through a forthcoming assessment of our initial study.

CONCLUSIONS

GIS mapping is yet another juncture in the ongoing struggle between modern and post-modern perspectives of research interpretation, pitting advances of empirical science against critiques of sweeping narratives and frameworks that mask and disregard the voices of those not part of the dominant milieu. Like other contested ground (gender, the media, public policy, etc.), the fight did not originate with this topic, and though GIS mapping may provide an arena where these ongoing feuds can find new expression, neither will it see its conclusion. However, similar to the history of feminist critiques of the natural sciences (Harding, 1996; Keller, 1982), as criticisms of power use and resource access were gradually acknowledged by the established order, one positive outcome has been an increasing openness, dialogue, and tendency toward scholarly self- policing. Despite occasional blazes of vitriol on both sides, ground gained as the legitimacy of criticisms are gradually acknowledged leads to a movement toward a self-policing and critiquing community of scholars and practitioners. The emergence of PPGIS is an example of just such an intra-field adjustment. This peer group is, at its best, aware of the tendencies of the discipline to exclude the perspectives of individuals and groups and is willing to engage in a lively dialogue about power, privilege, access, and voice. Nevertheless, the broad application and increasing accessibility of GIS in recent years has resulted in a range of constituents attracted to the representational and analytic opportunities it affords, with little to no appreciation for or interest in the epistemological issues and conversations related to its use. In other words, the opportunities for intentional and unintentional abuse grow when such tools are used apart from the influence of peer review and professional interaction.

The proliferation of GIS mapping as a promoted commodity adds an additional layer to concerns about ethical use and social responsibility. As we developed our project, our partner geographer was aiding in the creation of a campus-based, grant-funded, multi-million dollar GIS laboratory aimed at developing its own geographic projects as well as promoting inter- and multi-disciplinary partnership projects across the institution. At no point did this professional geographer engage with us in a conversation about the implications of mapping apart from base data accuracy. Whether it was his responsibility to do so is part of the question we broach here. The simple allure and self-evidence of mapping, particularly in projects designed for consumption by the uninformed patron, indicates that GIS and next-generation mapping software will continue to grow in popularity. Whether the burden of responsibility for fair representation rests with the researcher, the geographer, the policy-maker, or the consumer is vital question and worthy of further conversation.

As we invested in the mapping process and committed time and resources to this representational form, the demands of the mapping process increasingly shaped how we formatted data to comply with the GIS software. The format of the data, in turn, impacted how

we interacted with the data, how we thought about the data, how we talked about the data, and ultimately as well, the sense we made of the data. Gradually, mapping changed from a logistical and representational tool, to an interpretational agent. As mapping novices, we realized that not only could the mapping product impact unreflective audiences in potentially subversive ways, but also how the demands of mapping could impact our sense-making in the process of data analysis in ways that might not be just, equitable, or even ethical to groups or individuals represented by the data.

Certainly, our research team is neither the first nor the last to discuss the challenges of data representation and interpretation. Other researchers have encountered similar challenges through traditional visual methods (Cooper et al, 2003; Crowe, 2006; Weaver & Converse, 2008). However, we intend this paper to introduce some of the challenges, issues, and obstacles unique and related to GIS map use in general, and mapping access provider organizations in particular. At the state level, a full assessment of access provider resources is a laudable goal, especially given the calls for increased numbers of college graduates. However, conveying needs and resources must be done with care. The debate over racial and ethnic categorization by governmental and educational entities highlights both the frequently spurious process of category development and the far-reaching implications of those metrics (Omi, 1997). Similarly, mapping in this context is a relatively simple process with extensive social and political consequences.

Thus, we suggest three specific areas for ongoing map-related conversations related specifically to college access, and generally to the study of higher education. First, stakeholders interested in college access as a state policy issue need to engage in a dialogue about how to count and categorize college access providers and ways to transmit that data to interested parties, including legislators, educators, private citizens, and the access providers themselves. We hope that the work emanating from our original study is contributing to this goal. Second, educational researchers must engage in a dialogue regarding the hazards and benefits of using GIS mapping as a tool for representing geographically-based data, including sensitive demographic, achievement, and resource information. We found both positive and negative research experiences associated with the GIS mapping and interpretation processes. Finally, researchers, practitioners, and policymakers using these tools have a duty to participate in the ongoing dialogue about the responsibilities of scholars using GIS mapping, and to reflect on the expedience and accessibility of the medium when delivering data into the public policy arena.

REFERENCES

Aitken, S. C., & Michel, S. M. (1995). Who contrives the "real" in GIS? Geographic information, planning and critical theory. *Cartography and Geographic Information Systems*, *22*(1), 17-29.

Cabrera, A. F., & La Nasa, S. M. (2001). On the path to college: Three critical tasks facing America's disadvantaged. *Research in Higher Education, 42*, 119-149.

Cooper, R. J., Schriger, D. L., Wallace, R. C., Mikulich, V. J., & Wilkes, M. S. (2003). The quantity and quality of scientific graphs in pharmaceutical advertisements. *Journal of General Internal Medicine, 18*(4), 294-297.

Crowe, A. R. (2006). Technology, citizenship, and the social studies classroom: Education for democracy in a technological age. *International Journal of Social Education, 21*(1), 111-121.

Gandara, P. C., & Bial, D. (2001). *Paving the way to postsecondary education: K-12 intervention programs for underrepresented youth*. Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Gergen, K. J. (1992). Organizational theory in the postmodern era. In M. Reed and M. Hughes (Eds.). *Rethinking organization: New directions in organizational theory and analysis* (pp. ##). London: Sage.

Gersmehl, P. (1985). The data, the user and the innocent bystander: A parable for map users, *The Professional Geographer*, *37* (3), 329-334.

Ghose, R. (2001). Use of information technology for community empowerment: Transforming geographic information systems into community information systems. *Transactions in GIS, 5*(2) 141-163.

Gullatt, Y., & Jan, W. (2003). *How do pre-collegiate academic outreach programs impact college-going among underrepresented students?* Boston: Pathways to College Network Clearinghouse.

Haque, A. (2001). GIS, public service, and the issue of democratic governance. *Public Administrative Review, 61*(3), 259-265.

Harding, S. (1996). Feminism, science, and the anti-enlightenment critiques. In Ann Garry and Marilyn Pearsall (Eds.). *Women, knowledge and reality: explorations in feminist philosophy*. London: Routledge.

Keller, E. F. (1982). Feminism and science. *Feminist Theory, 7*(3), 589-602.

Kwaku Kyem, P. (2004). Of intractable conflicts and participatory GIS systems: The search for consensus amidst competing claims and institutional demands. *Annuls of the Association of American Geographers, 94*(1), 37-57.

MacEachren, A. M. (2000). Cartography and GIS: Facilitating collaboration. *Progress in Human Geography, 24*(3) 445-456.

Monmonier, M. (1991). *How to lie with maps.* Chicago: The University of Chicago Press.

Obermeyer, N. J. (1998). The evolution of public participation GIS. *Cartography and Geographic Information Systems*, *25*(2), 65–66.

Omi, M. (1997). Racial identity and the state: The dilemmas of classification. *Law and Inequality, 7*(19).

Perna, L. W., & Swail, W. S. (2001). Pre-college outreach and early intervention. *Thought and Action: The NEA Higher Education Journal*, *27*, 99-110

Perna, L. W. (2002). Precollege outreach programs: Characteristics of programs serving historically underrepresented groups of students. *Journal of College Student Development, 43*(1), 64–83.

Pickles, J. (1995). Representations in an electronic age: Geography, GIS, and democracy. In J. Pickles. (Ed.). *Ground Truth* New York: Guilford Press.

Schuurman, N. (2000). Trouble in the heartland: GIS and its critics in the 1990s. *Progress in Human Geography, 24*(4), 569-590. DOI: 10.1191/030913200100189111

Sheppard, E. (1995). GIS and society: Toward a research agenda. *Cartography and Geographic Information Systems, 22*(1), 5-16.

Sieber, R. (2006). Public participation geographic information systems: A literature review and framework. *Annuls of the Association of American Cartographers, 96*(3) 491-507.

Tierney, W. G. & Jun, A. (March–April 2001). A university helps prepare low income youths for college: tracking school success. *The Journal of Higher Education, 72*(2), 205–225.

Taylor, P. J. (1990). GKS. *Political Geography Quarterly*, *9*, 211-212.

United States Geological Survey. (2007, February). *Geographic Information Systems.* Retrieved from http://egsc.usgs.gov/isb/pubs/gis_poster/

Weaver, C. L., & Converse, D. (2008). Picture this: Strategies for communicating data to decision makers. *NASJE News Quarterly, 23*(4). Retrieved from http://nasje.org/news/newsletter0804/02-resources01.php

APPENDIX 1