Public Health Education and Practice Using Geographic Information System Technology
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Abstract The use of geographic information system (GIS) technology allows public health practitioners to explore disparities in health, analyze disease outbreaks, and prioritize the use of limited resources for improving population health. Nursing students benefit from use of World Wide Web GIS resources as they develop knowledge and skill in assessing population health and planning interventions. This article identifies the benefits of GIS for public health practitioners, presents a communicable disease control application of GIS, and discusses a GIS module used in an undergraduate nursing education course. Uniform standards for making health data available for public use with GIS are discussed.

Key words: public health education, geographic information practice.

Creating a visual picture of information can assist public health practitioners in understanding and using knowledge in new ways. A visual synthesis of large amounts of abstract information into a picture representative of a geographic area is important for students and practicing public health nurses. This visualization of information allows the creation of linkages between separate pieces of information and their geographic distribution. It can facilitate in-depth understanding and can suggest solutions to public health problems.

Public health practitioners have always plotted disease information geographically, yet this has been very labor intensive and also limited in relation to specificity, detail, and changes adaptable to multiple population aggregates. Integrating geographic information system (GIS) technology, which is efficient and useful, into their practice to fulfill local, state, and national expectations of population assessment has allowed practitioners to more adequately perform this key function of public health agencies. This leading-edge technology is now being taught in many disciplines within higher education, and preparing nursing students to function in the technology-oriented information environment that currently exists within public health agencies is important for schools of nursing.

GISs are powerful software tools available to universities, public health agencies, and other organizations that combine geography, data, and computer mapping. With GIS, digital maps and databases are stored with linked geo-referenced identifiers to facilitate rapid computer manipulation, analysis, and spatial display of information. Geocoding (assignment of an x and y coordinate, such as latitude and longitude, to an address for placement on a map) will be the basis for a great deal of data linkage and analysis in the twenty-first century. The versatility of GIS allows the exploration and identification of...
spatial relationships, patterns, and trends that otherwise may go unnoticed.

Geography is concerned with the identification and explanation of spatial structure, pattern, and process, as well as the analysis and explanation of the links between people and the environment. Because epidemiology is the study of the distribution and determinants of disease and injury in populations and of factors that influence this distribution, geography has a logical fit in many epidemiologic studies (Mayer, 1983).

The development of GIS over the last 20 years has provided powerful and rapid computer technology tools for examining spatial patterns and processes (Moore & Carpenter, 1999). Epidemiologists understand that disease processes have an historical (time) component, and formal methods of time series and hazard analyses are well developed to study them. Fewer tools, however, have been available to study an equally important aspect of epidemics—their geography or space.

This article presents two examples of how GIS can be used in community/public health nursing (C/PHN) practice and education. The first application describes an actual use of GIS by a metropolitan public health agency in responding to a shigella outbreak. The second describes a nursing education application in which GIS was integrated into an undergraduate community health nursing (CHN) course. Finally, available Internet-based GIS databases are described, and suggestions for ways in which professionals can incorporate GIS into their practice are provided.

ROLE OF GIS IN PUBLIC HEALTH

In 1854, prior to the information age and development of GIS, Dr John Snow demonstrated the importance of the geography of disease events for the city of London (Snow, 1994). When Snow mapped cholera cases, nebula-like spatial clusters with distance-decay effects were readily apparent. His maps led to the hypothesis that one particular water supply was the source of the outbreak. Without even knowing the bacterial cause or means of transmission of cholera in the mid-nineteenth century, he was able to quell the outbreak once he understood the spatial aspects.

The logic of using geography to study disease and health is derived from appreciation of factors causing non-uniformity of disease distribution, just as Dr Snow discovered. These factors include physical and environmental factors, social, economic, and cultural factors, and genetic factors (Moore & Carpenter, 1999). For example, diseases may be associated with environmental pollution, linked to individual or group behaviors, or associated with a genetic predisposition. One of the main applications of epidemiology is to facilitate the identification of geographic areas and population groups that present a relatively greater disease or death risk and therefore require more preventive or curative care as well as health promotion.

The use of GIS has expanded since its inception as an analytical tool. It has been used in the public health care arena, for example, to assist in epidemiology (Castillo-Salgado, 1996; Moore & Carpenter, 1999; Richards & Croner, 1999), to enhance community-based child welfare services (Robertson & Wier, 1998), and for community program evaluation of changes in alcohol outlet distribution (Millar & Gruenewald, 1997). GIS has been used in the surveillance and monitoring of vector-borne and water-borne diseases, quantifying lead hazards in a neighborhood, predicting child pedestrian injuries, and analyzing disease policy and planning (Clarke, McLafferty, & Tempalski, 1996).

Identification of groups affected by particular health problems allows the selection of appropriate social and health interventions aimed at reducing or eliminating specific risk factors. Once interventions have been carried out, their impact on health status must be evaluated to determine their effectiveness and whether adjustments in the interventions are needed. This dynamic process of diagnosis–action–evaluation–adjustment is a part of the epidemiological stratification methodology.

Institute of Medicine (1988) identified the mission of public health as to fulfill society’s interest in assuring conditions in which persons can be healthy. The three core public health functions identified by the Institute of Medicine that have increasingly become the hallmark of effective practice and program management were assessment of information on the health of the community, comprehensive public health policy development, and assurance that public health services are provided to the community. These functions have been used by C/PHN organizations to develop practice frameworks.

The Quad Council (1993), whose members represent the specialty C/PHN organizations, identifies the goal of population-focused practice as promoting healthy communities. The Quad Council addresses each of the core functions in relation to the role of the C/PHN. Community assessment of health risk factors and disease indicators requires the nurse to: (1) evaluate demographic, epidemiologic, and biostatistical data to anticipate and identify risks and patterns of morbidity and mortality; (2) evaluate changing health behaviors and patterns that have the potential to place people at risk;
and (3) determine other indicators to monitor the dimensions of health status valued by the community. Each of these functions can be enhanced by the use of GIS technology.

Policy development, the second core function of C/PHNs, is aimed at the reduction of health problems of the general population and subgroups. The data component of this function requires community nurses to analyze assessment data to identify potential and actual health problems, from which policy advocacy work can be initiated (The Quad Council, 1993). GIS technology can be used to provide education about the distribution of health indicators to key persons.

Assurance of access, the third function, focuses on the accessibility of services to promote the effective implementation of policy at the service-delivery level. For this function, nurses use data to evaluate access to, use of, and distribution of services in the population. Changes in health status are outcomes that can be used by nurses to evaluate access over time (The Quad Council, 1993). GIS technology can enhance the understanding of the distribution and characteristics of health indicators over time from visual displays.

GIS technology can help population-based nurses more effectively support the health of their community in the multiple roles they regularly carry out. The Public Health Nursing Interventions Model (Keller, Strohschein, Lia-Hoagberg, & Schaffer, 1998) provides a description of the individual, community, and system focus involved in this practice field. Appendix 1 describes some of the interventions promoted in this model and describes ways in which GIS technology can be used to facilitate the work.

Public health nurses operate within the national health care system as interdisciplinary team members. The Healthy People 2010 (HP 2010) plan is a systematic approach to health improvement in the United States (United States Department of Health and Human Services, 2000). It represents the ideas and expertise of a diverse range of individuals and organizations concerned with the nation’s health. HP 2010 was designed to achieve two overarching goals: increase quality and years of healthy life and eliminate health disparities. Mapping of health and community characteristics of the HP 2010 objectives can increase the broad-based coalition building important in achieving the objectives.

The public health infrastructure is one of the focus areas of the HP 2010 plan and has 17 objectives. Three objectives are particularly relevant to community-oriented nurses’ access to population health data. These objectives include: (1) public access to information and surveillance data; (2) use of geocoding in health data systems; and (3) data for all population groups.

Public health rests on information. The information technology revolution, including online systems, the Internet, and other electronic information systems, continues to expand both the volume and the accessibility of information. Increased use of geocoding in health data systems will provide the basis for more cost-effective disease surveillance and intervention. At the same time, challenges arise in synthesizing and disseminating the huge amount of available information, as well as ensuring that the data are scientifically accurate and have appropriate safeguards for confidentiality. The capacity to achieve national goals is related to the ability to target strategies to particular geographic areas. Extension of geocoding capacities throughout health data systems will facilitate this ability.

**APPLICATION**

In the following section, two applications of GIS are discussed. These applications illustrate how GIS can be integrated into public health practice and baccalaureate nursing education.

**Shigella Outbreak Application at a Local Health Department**

In response to increasing reports of shigellosis in the spring of 2000, the Marion County Health Department, Indianapolis, IN, enlisted the support of the Health Department’s GIS department. Shigella, a highly infectious type of bacteria, is spread through the fecal–oral route and rapidly moves through communities where hygienic practices are compromised or in cases where food and water sources have been contaminated. Shigella has a short incubation period (12–96 hr) commonly followed by fever and severe diarrhea. Seventy-six cases for the first quarter of 2000, compared to a single case reported in the first quarter of 1999, heightened the intensity of surveillance and increased scrutiny of cases for common links. Shigellosis is reportable by law in Indiana, and all laboratories that have positive tests are required to report the findings immediately. Within 24 hr of reporting, investigation of the case begins. If contact cannot be made by telephone, home visits occur. Investigative reports include demographics, onset of symptoms, and treatment. The locations of home residence, schools, day care, and employment are also recorded.
The age of the person with shigella became a significant marker in the identification and location of new cases. Of the total 1315 cases reported in 2000, 824 (63%) were in preschool-age children. In monitoring the 2000 outbreak, GIS mapping configured data in two different ways. The residence of the case was mapped to determine whether there were significant clusters in any neighborhoods (Appendix 2), and secondly, day care centers were mapped when a confirmed case attended or worked in the center. Day care centers and residences could be linked to determine the source. Secondary cases were identified in children in the same day care centers and in family members with preschoolers. GIS mapping visually located the hot spots in the city, and weekly overlays of new cases were developed to show the new areas where infectivity was occurring. By locating day care centers and neighborhoods where there was a concentration of cases and where new cases were occurring, interventions could be directed in the appropriate locations and priorities could be set.

Public health nurses were enlisted to work with day care directors and parents, first in the geographic areas of greatest case counts and moving out to areas of fewer incidents. Ninety public- and private-school sites had diagnosed cases of shigellosis. Public health nurses worked with sites to assure compliance with State Board of Health guidelines for management of the disease and in the distribution of handwashing videos and teaching. The GIS maps also provided a monthly visual for a county task force comprised of persons from the public and private community. These maps provided a clear picture of the initial cases and the continued occurrence of disease, which helped to determine the need for other interventions such as written advisories and posting of handwashing signs in public facilities with high utilization, such as the airport.

Cases of shigellosis peaked in May, with 337 diagnosed cases, and began to decline throughout the summer. Application of public health surveillance principles and investigation methods, enhanced by GIS mapping, assisted in directing appropriate interventions.

NURSING EDUCATION MODULE ON GIS

The opportunity to integrate this leading-edge technology into C/PHN education occurred when a new BSN curriculum was adopted at our school. Three curriculum outcomes were identified that lent themselves to the integration of GIS technology. These outcomes required students to be able to: (1) synthesize prior knowledge with current information regarding the health of the community in appropriately responding to new situations; (2) manage information data sets and utilize these data sets for community-based problem solving; and (3) independently examine multiple approaches in seeking community-oriented care solutions to identified community-based health problems.

Previously, students performing population-based assessments, who needed to visually display geographic features, used hand drawings to show distribution of census information, location of health care agencies, community agencies, and organizations. They drew on city maps with colored pencils and markers and used stickers to depict location of services such as hospitals and community agencies.

In recent years, the increasing number of service-learning partnerships between the school of nursing and community agencies has created the opportunity for students to perform population-based assessments for service agencies. The results of the assessment are often presented to agency boards or groups of administrators and staff. Students have become increasingly competent in integrating Power Point slides and digital pictures of the service area into these presentations. Use of GIS maps will allow them to replace their hand-drawn visual aids with high-quality, comprehensive population maps. It will allow students to use mapping technology to display the natural features, integrate health and social service data into visual displays, and increase understanding of how multiple sources of data are related and affect each other.

LEARNING MODULE DESIGN

This technology innovation was embedded within a larger module of the CHN course that included epidemiology and biometrics. Students had previously been introduced to assessing community health through the use of census data, epidemiological data, and social/political/economic data at the local, state, and national levels. In addition, they had learned about how the data are obtained, how to interpret them, and how to apply them to solve problems. They were also introduced to the Social Assets and Vulnerabilities Indicators (SAVI). Data contained in the SAVI system for the Indianapolis metropolitan area are described later in this article. This information helped students understand the benefits and capabilities of the SAVI data. The learning module integrated four types of instructional strategies: didactic instruction that included a presentation of GIS-supported maps used in local public health work; a tutorial with in-class demonstration of the software program;
supervised small-group tutoring sessions; and a GIS assignment.

Using the student-learning objectives, staff from The Polis Center developed a web-based tutorial on the use of the SAVI file of social demographic and asset data for our nine-county metropolitan area. The tutorial was designed to help students learn to use the software, while also creating a map of a population they were interested in knowing more about. It integrated a student assignment with the basic software instruction. This seemed to ease the students’ anxiety about the new software. The tutorial allowed them to follow each click of the mouse as the decisions were made during the development of the map (Appendix 3).

Principles of good education (Chickering & Gamson, 1987; Chickering & Ehrmann, 2000; King, 2000) were integrated into the new GIS module. Specifically, the module was designed to maximize the efficiency of time on task, communicate high expectations, respect diverse talents and ways of learning, as well as allow opportunities for student cooperation. Faculty offered initial tutoring sessions to help learn the software. In addition, students could request individual assistance and be tutored at specific points. To promote active learning, however, students also were given a printed and web-based tutorial to assist them in developing skill in working with the technology. Students completed the assignment in 3 weeks. During that time, they often sought out feedback on their performance and worked with peers. Suggestions were made for specific problems, and students were encouraged to work with a student who had been successful with the assignment.

STUDENT PROJECT

The students created two maps based on either the community they were working with in the clinical practicum or the population-at-risk they were researching for their term paper. They then wrote a descriptive paragraph about their interest in this population and what information the maps provided. Students developed a community nursing diagnosis using information from the maps and learning from previous courses and life experiences.

The narrative description of the maps indicated that students were able to select data sets within those available to explore population issues. Because many of the data sets had subdivisions within them, the students gained experience in selecting meaningful indicators and appropriate denominators. They could select rates or numbers and identify characteristics that were dense or sparse. Students were able to combine more than one indicator on a map and display the overlap in information. For example, one student showed the location of a minority population within the community and overlaid that with number of low-birth-weight babies, thereby learning about local health disparities.

The projects submitted revealed that students were able to learn the software and produce two maps showing different features of a community. A grading rubric was developed to evaluate the students’ work, which was used to evaluate the various features of the assignment and give students feedback.

A quantitative tool was developed for students to evaluate the GIS module. Three items assessed students’ perceptions of meeting the key curriculum goals for this module. Students reported that they could see how to use the maps for community-oriented problem solving, could synthesize prior knowledge about a population with current information, and could apply multiple approaches in seeking community-centered care solutions to problems.

Four items were included from The Flashlight Assessment Project which is a national effort to assess students’ use of technology as an education methodology (Ehrmann & Zuniga, 1997). These items focused on skill and comfort in the utilization of technology. Students’ responses indicated that they could see the results of their work almost immediately, spent too much time learning to use SAVI, and yet were encouraged to exercise their creativity. They did not feel at a disadvantage because they did not possess adequate computer skills. This was very encouraging because the software was not necessarily intuitive, and they were using new technology skills to negotiate databases they were also learning to use and interpret. Students did not view the software as making the assignment more interesting. These students, however, had not had experience with the more tedious former methods of displaying geographic data by hand, coloring in black and white boundary maps to depict variation in incidence and rates and locations of community agencies.

Six items representing principles of active learning were threaded into the evaluation tool. Students believed that they were likely to work on assignments with other students, ask other students for comments on their map or table, and produce one or more versions of a map or table before producing the final product. Students reported that they got individualized attention from the instructor but may have missed important information because they moved through the assignment too quickly.
EXPLORING GIS RESOURCES

The Indianapolis metropolitan area is unique in that it has a publicly accessible GIS-enabled warehouse of social demographic data contained in the SAVI program. SAVI is a partnership between the United Way of Central Indiana and The Polis Center at Indiana University Purdue University Indianapolis. This system combines a wide variety of social indicator data with service-provider data. The social demographic data include hundreds of data categories compiled from vital statistics, crime, juvenile court, welfare, education, census, and home lending data. These data are aggregated according to a variety of geographies for public distribution. There are also hundreds of service-provider categories including such things as schools, day care centers, hospitals, places of worship, libraries, etc. The service providers are released as data points, i.e., specific address locations. All of the SAVI data are released to the public via access sites. A more limited set of data is available via SAVI Interactive on the World Wide Web. The access sites are local entities where there are trained analysts who assist the public in accessing the data contained in SAVI either in tabular or map form. Access sites are located throughout the metropolitan area within public agencies. The City of Indianapolis, the Public Library, and the United Way are among those serving the user community. SAVI Interactive, an interactive website that allows users to create and query maps and tables, has also been developed to serve the user community. This site includes tutorials as well as extensive documentation about the data included, and this site is available to anyone with Internet access. The site is somewhat more limited in the amount of data available but has greatly enhanced the accessibility of the SAVI data.

Although Indianapolis is a leader in providing publicly accessible social indicator data, many similar systems are being developed across the country. Notably, there are several cities involved in the National Neighborhood Indicators Partnership coordinated by the Urban Institute (http://www.urban.org/nnip/) that have varying levels of public access. A major challenge in the coming decade will be to increase public access to GIS-enabled information without compromising the confidentiality of individuals. The National Center for Health Statistics sets the standard for release of health data. Their guidelines are summarized in Appendix 4.

Obviously, not all communities have access to a SAVI system of local data. As the application of GIS-enabled data expands, however, more communities will have access to interactive mapping systems with local data (Appendix 5). Every 10 years, the U.S. Bureau of the Census compiles the most comprehensive set of social demographic data available. At this writing, the most comprehensive source of GIS-enabled local data available for all areas in the nation is the U.S. Bureau of the Census Data. Much of the census data is available via the World Wide Web.

CONCLUSION

This article discussed leading-edge GIS technology that is particularly relevant to the practice of C/PHN. Our new education module involved a creative redesign of teaching/learning strategies for the community-assessment component of an undergraduate course. Use of GIS technology in monitoring a communicable disease outbreak facilitated a strategic intervention control response. And finally, the SAVI database has allowed the Indianapolis metropolitan area to enhance their assessment of community characteristics and assets for the purposes of planning, coordination, and intervention.

There is great potential for GIS to facilitate the future work of public health. As students graduate and enter the workforce, they bring these skills in assessing population health using Internet databases. These skills can be useful in health care agencies where nurses are instrumental in planning and evaluating services for populations in their service area.

GIS technology is being integrated into a graduate CHN course at Indiana University—Indianapolis that uses a problem-based learning format. Training has been provided to campus and non-campus faculty in health profession schools and to public health nurses in the metropolitan area served by the database.

REFERENCES


### APPENDIX 1

**Application of Geographic Information System Technology to Population-Based Interventions**

<table>
<thead>
<tr>
<th>Population-based interventions</th>
<th>GIS application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Surveillance</td>
<td>Develop or access a GIS database to monitor indicators of health, incidence of disease, and vital statistics within a community.</td>
</tr>
<tr>
<td>Social marketing</td>
<td>Use data maps to provide a visual picture for planners, educators, and marketing specialists that depict indicators of health and illness for use in developing marketing strategies to design education campaigns to influence and improve the health behaviors of target groups and populations.</td>
</tr>
<tr>
<td>Health education</td>
<td>Select sites throughout the community using GIS technology that target areas in highest need for education to maximize efforts and financial resources. Maps can also identify community agencies in the targeted areas where the education programs can occur.</td>
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<tr>
<td>Community organizing</td>
<td>Display large amounts of information about community resources or assets that display location and distribution throughout the area.</td>
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<tr>
<td>Collaboration</td>
<td>GIS maps and databases can assist collaborating agencies to exchange information about their population characteristics and trends with each agency sharing unique information.</td>
</tr>
<tr>
<td>Outreach/case finding</td>
<td>Outreach/case finding activities can be justified and planned based on GIS maps. Identifying selected census tracts with the greatest incidence of disease provides administrative support for the expensive work of case finding.</td>
</tr>
<tr>
<td>Coalition building</td>
<td>Use of data maps to provide visual pictures of areas with the highest incidence of disease can motivate development of coalitions to design effective campaigns for targeted populations.</td>
</tr>
<tr>
<td>Advocates</td>
<td>GIS technology can assist in groups to present a strong policy argument for why new resources should be allocated or there should be a re-distribution of existing resources for treating and preventing diseases or illnesses.</td>
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</tbody>
</table>

Interventions are based on Keller, Strohschein, Lia-Hoagberg, and Schaffer (1998). The Quad Council, 10 Essential Functions of PH.
APPENDIX 2

Zoom in to magnify cross-hatched census tracts

- Note the census tracts in which the query layers intersect
- These tracts reflect the location of populations that have
  - inadequate resources for food purchase and
  - have given birth to low-weight infants

APPENDIX 3
APPENDIX 4

Guidelines

In no table should all cases of any line or column be found in a single cell
In no case should the total figure for a line or column of a cross-tabulation be less than 3
In no case should a quantity figure be published if one case contributes to more than 60% of the amount
In no case should data on an identifiable case, nor any of the kinds of data listed in preceding items A–D, be derivable through subtraction or other calculation from the combination of tables published on a given study
Data published by NCHS should never permit disclosure when used in combination with other known data

APPENDIX 5

Some of the 1990 census data are available through the ESRI website at http://www.esri.com/data/online/index.html. At the ESRI site, the user can “make [a] quick map” online showing census tract-level demographic information from a select set of census data. American FactFinder at http://factfinder.census.gov/servlet/basicfactservlet will allow the user map a broader array of 1990 and 2000 census data at the county level.

In addition to these national sources, several cities have sites that will allow for analysis similar to that done in Indianapolis using the SAVI database. These include The Cleveland Area Network for Data and Organizing (CAN DO) (http://povertycenter.cwru.edu/cando.htm)—this website gives users the option of creating census tract-level maps for a variety of data including population, poverty, income, households and families, education, employment, housing, and residential mobility data from the U.S. Bureau of the Census (1990) and education, housing, child maltreatment, public assistance, vital statistics, and crimes and safety data from a variety of other sources—and Piton Foundation, Denver (http://www.piton.org)—this site allows the user to create tract maps from a variety of demographic, housing, economic, education, crime, and health variables derived from a variety of sources including the 1990 Bureau of the Census Data.

SAVI, Social Assets and Vulnerabilities Indicators.