GeoSim: A GIS-Based Simulation Laboratory for Introductory Geography

by Laurence W. Carstensen, Jr. , Clifford A. Shaffer, Robert W. Morrill, and Edward A. Fox

DEPARTMENTS OF GEOGRAPHY AND COMPUTER SCIENCE, VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY, BLACKSBURG, VIRGINIA..

Project *GeoSim* is a multidisciplinary effort by members of Virginia Tech's Departments of Geography and Computer Science, College of Education, and Learning Resources Center to develop computer-aided education (CAE) software for introductory geography and related classes. *GeoSim* laboratory exercises draw on the five fundamental themes of geography for their subject matter. The programs emphasize interactive learning combining the information capabilities of Geographic Information Systems (GIS) with the techniques of computer simulation. The result is a series of geographic explorations that will make available some of the most exciting aspects of geography to a potential audience of 425,000 introductory geography students per year. **Key words:** *interactive learning, five fundamental themes, introductory geography, GIS, simulation.*

Geography and Its Place in the Curriculum

Geography is unique among disciplines in its focus on the spatial aspects of physical processes and human actions. Understanding historical and contemporary events requires knowledge of geography. Yet, dozens of studies point out the geographic incompetence of students in the United States, partially due to the historic lack of geography offerings at the primary and secondary levels, and partially due to the nature of traditional college teaching methods in the field which often emphasize lecture and examination over hands-on interaction (Bettis 1990; Dallas Times-Herald 1983; Commission on International Education 1984). For many disciplines, lecture-based instruction is very effective, as the narrative is the major means of communication. In geography, however, the most significant aspects include dynamic processes. While geography can be described and viewed through a series of visual aids (films, slides, and videos), dynamic processes can be better grasped when experienced through active manipulation of data using geographic theory. The popularity of widely offered techniques courses such as cartography, remote sensing, and geographic information systems attests to the enthusiasm students feel for applying geography to real problems.

Yet, these courses are usually offered only to relatively few advanced students. At the opposite extreme, introductory human geography is often taught to large sections (Virginia Tech is typical, with 60-200 students per section), making hands-on interaction between students and geographic applications difficult. Reduced budgets at many colleges and universities in the United States exacerbate the problem. Technology to instruct via computer-administered material can be an effective, engaging, and cost-saving alternative to group instruction in the classroom. Unfortunately, a large portion of current geographic software focuses on basic concepts and rote learning (almost always place-name geography) rather than on geography's systematic approaches to studying world problems (TESS 1988). Because students understand better by "doing" than by "hearing about," interactive applications of geographic theory offer the most exciting promise for improved instruction in introductory geography.

The Five Fundamental Themes of Geography

To instill a structure for developing a unified approach to teaching geography, the Guidelines for Geographic Education (JCGE 1984) articulated five fundamental themes appropriate for inclusion in geography curricula: 1) Location: position on the Earth's surface, 2) Place: physical and human characteristics, 3) Human/Environment Interactions, 4) Movement: humans interacting on the Earth, and 5) Regions: how they form and change. In 1991, President Bush issued *America 2000: An Education Strategy* calling for "challenging subject matter" in five core subjects including geography (*America 2000*1991, 62). In 1992, the Geography Assessment Framework for the 1994 National Assessment for Educational Progress (NAEP 1992) emphasized the use of the five themes as content organizers in the pursuit of better geographic education. Though the five themes are widely accepted and used in K-12 educational efforts, their adoption at the college level has been slow. Only in 1990 did the first college textbook organized around the five themes appear (Hardwick and Holtgrieve 1990).

Project *GeoSim*

This paper describes project *GeoSim*: a multidisciplinary effort by members of Virginia Tech's Departments of Geography and Computer Science, College of Education, and Learning Resources Center to develop computer-aided education (CAE) software for introductory geography and related

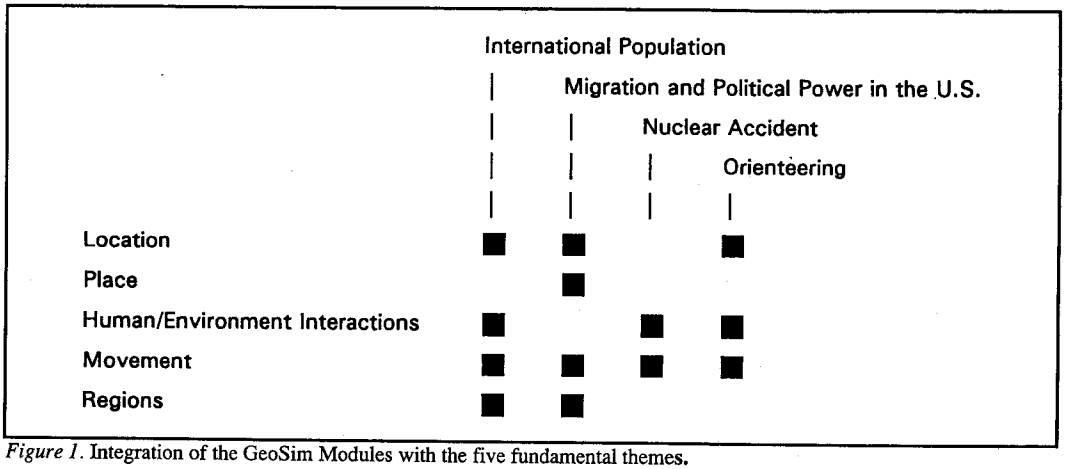

Figure 1. Integration of the GeoSim Modules with the five fundamental themes.

classes. *GeoSim* modules are designed to teach students the concepts of dynamic spatial processes embodied in the five themes. Interactive exploration of these processes is at the heart of all the *GeoSim* modules. The modules combine the impressive information presentation and analysis capabilities of geographic information systems (GIS) with interactive techniques of computer simulation. Historically, due to the complexity of GIS, geographic data handling and analysis have been reserved for technically oriented courses at the advanced college level. Yet, through a multidisciplinary approach aimed solely at educational needs, it is possible to automate the use of GIS so a full understanding of spatial and statistical analysis techniques is not a prerequisite to learning from them.

The initial focus of *GeoSim* is the creation of a series of four computer modules: International Population, Migration and Political Power in the United States, Nuclear Accident, and Orienteering. Through a study of texts commonly adopted for introductory courses, we are assured that the topics selected illustrate material already commonly taught in introductory geography (Getis, Getis, and Fellman 1991; DeBlij and Muller 1991; Fellman, Getis, and Getis 1992; Rubenstein 1992; Bergman and McKnight 1993). In each module, several of the five fundamental themes of geography are emphasized (Figure 1) so as to form a bridge from familiar material in the precollegiate environment to collegiate geographic education.

The Potential Audience

During the 1990-91 academic year, more than 425,000 undergraduate students enrolled in introductory geography courses (Walker 1991). Students taking introductory geography are quite diverse with one commonality—they likely have not experienced a geography course before. As an example, each year at Virginia Tech, over 500 students enroll in GEOG 1004: Introduction to Human Geography. A great majority are not majors but have chosen geography to fulfill a university core curriculum requirement. Many are undecided about their futures and take geography as an experiment because they know little about the field.

Currently, there is a widespread perception that geography is a passive subject based mainly on memorization. If the first geography course can stimulate students to active use of geographic concepts and inquiry, it could not only raise general knowledge of the world, but also instill a recognition of the value of the science of geography—in itself and as a component of many other sciences. Clearly, students who go on to study geography will benefit from a more effective introduction to their field; however, those who go on to other fields should also recognize the role of geography in their work. Biologists who study seed dispersal will note distinct geographic patterns of diffusion based on transport and climate. Entomologists may study the diffusion of insect pests such as Gypsy moths that damage trees, or of Africanized honeybees as they migrate through Texas and the U.S. Southwest. Electrical engineers might study the propagation of radio and microwaves across geographic regions. Civil engineers may model traffic flows along arteries or the slow movement of groundwater contamination through geologic substructures. Wildlife biologists could later study potential habitats by relating together geographically dispersed variables such as forest cover and food supply.

Modules

The four initial *GeoSim* modules will become parts of existing comprehensive courses without relying on instructors to modify their courses to "fit them in," or worse, to buy expensive equipment on which to operate them. The modules will run on IBM-compatible 80386 or higher machines (using MS DOS and WINDOWS), Macintosh II computers, and UNIX systems running X-Windows. The databases will be readily adaptable to local geographic areas and support examples of geographic inquiry that do not require specialized lectures for their use. The modules will fit closely into existing models of introductory geography as illustrated by current popular texts (Getis, Getis, and Fellman 1991; DeBlij and Muller 1991; Fellman, Getis, and Getis 1992; Rubenstein 1992).

Criteria for Learning Modules

To assure achieving our educational goals we have developed internal guidelines for *GeoSim* module selection. To be developed, an idea for a *GeoSim* module must fit a majority of the following: 1) clearly relate to introductory geography, 2) illustrate a topic that includes events and processes that affect a significant portion of the world's population, and also illustrate how the topic affects the student, 3) illustrate two or more of the five fundamental themes of geography, 4) illustrate a topic of enduring interest and importance, 5) facilitate student understanding through interaction with problem-solving oriented simulations, 6) illustrate a topic that is complex

enough to allow many possible solutions, is suitable for simulation, and is inquiry-based, 7) help students gain an understanding of the application of scientific methods in problem-solving and research, and 8) draw from a database that can be applied to the student's location and updated at appropriate intervals.

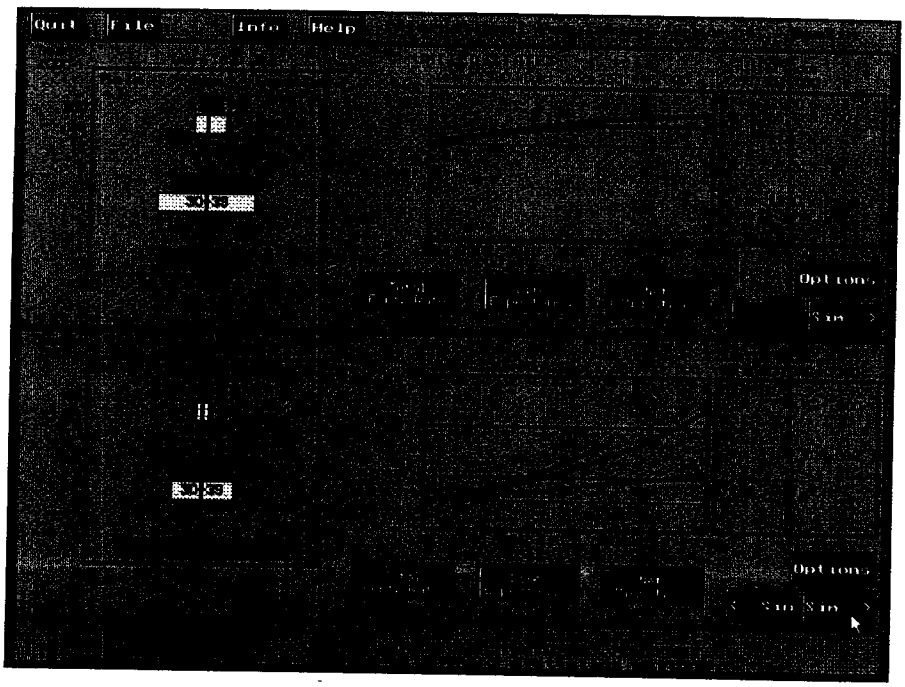

Figure 2. A sample screen from the International Population Module. In this example, the student is comparing Africa and the United States under different fertility assumptions. As the simulations are run, the population pyramids and line graphs are updated at five year intervals.

General Format of the Learning Modules

To simplify the use of *GeoSim* modules for both student and instructor, all will share the same menu-driven interface, and will adhere to the following sequence: 1) A tutorial of background material will be presented. The two major components will be information on the content of the module, and on the use of the module. 2) The primary interactive exercise will allow students to explore the material at their own pace. Students may repeat exercises as many times as they wish. Because of the simulation nature of the modules, to some degree, each experience is unique. During this phase, performance information will be collected automatically in a student log file for later use by the instructor. 3) The student's choices in the simulations will be carried out and evaluated by the module software with immediate feedback provided. 4) Where appropriate, some modules will provide post-exercise tutorials. These presentations will be directed in part by the student's performance on the exercise.

Module Descriptions

The modules briefly presented below are all technically feasible, as they are based on common capabilities of commercial and educationally oriented GIS, or well understood simulation techniques. They all meet most of the goals outlined above, and are all currently functional to varying degrees.

International Population:

General Description: This module allows students to explore a database of approximately 200 countries and aggregate regions regarding population growth. Students investigate both individual and interrelated effects of altered birth, death, and net migration rates on the population pyramids and total population levels of countries and regions (for a sample screen see Figure 2). The simulation supports comparison of two countries or regions simultaneously, and permits three different scenarios to be displayed at one time for each country or region. (A more complete description of this module is found in Shaffer et al. [1991]).

Specific Educational Goals: Human population change illustrates the fundamental themes of Location, Human/Environment Interactions, Movement, and Regions. The module's tutorial information emphasizes the effects that burgeoning populations have on the environment. In the simulation portion of the module, a country or region for study is selected either from a list or from a map. Use of the map reinforces knowledge of world location. The simulation also allows students to specify net migrations of people into or out of a country or region reinforcing the component of movement. Finally, through country comparison and numerous maps presented in the tutorial, students see that population structures group into regions. This module also provides experience with the scientific method as students predict the effects of changes in demographic variables or shifts in government policies and are provided immediate feedback on the validity of their hypotheses.

Migration and Political Power in the United States:

General Description: This module will allow students to relate county migration patterns in the United States. between 1950 and 1990 with data on place characteristics. Several exercises will be possible using the module's software, including: 1) simulating population changes in counties by extrapolating past trends; 2) selecting and weighting push and pull factors from 1950-1990 county census data in an attempt to model accurately migration patterns occurring during that time period (for a sample screen see Figure 3); 3) selecting and weighting criteria for personal residential desirability, and having the computer rank and display counties meeting personal requirements; and 4) examining the political effects of

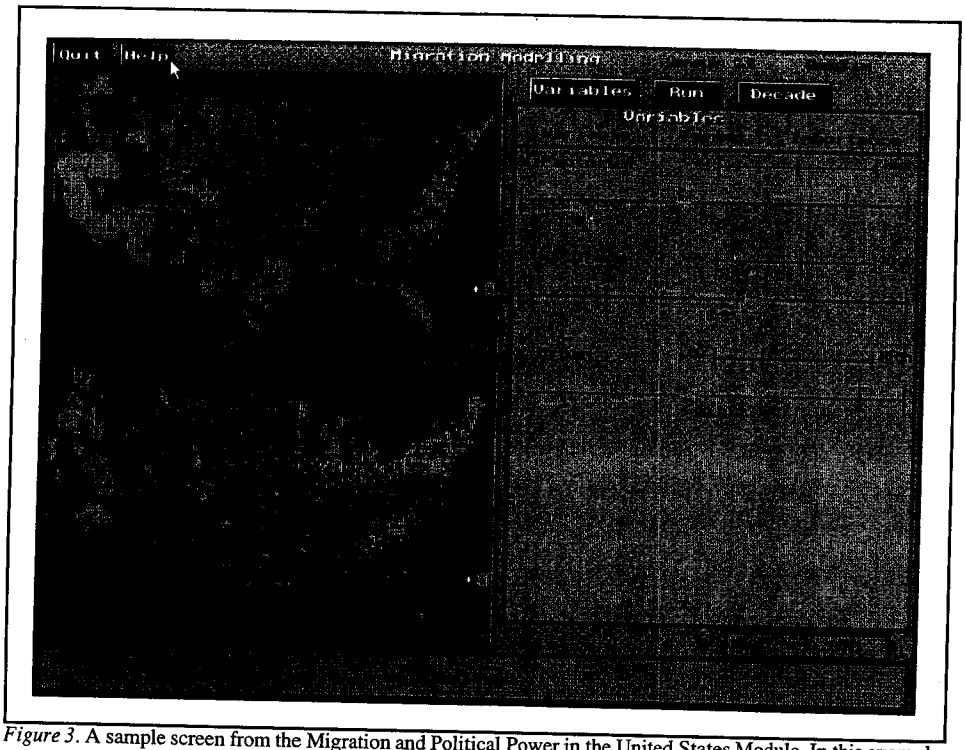

Figure 3. A sample screen from the Migration and Political Power in the United States Module. In this example, the student is attempting to model observed migration during the decade of the 1980s by suggesting that the presence of: 1) a large number of manufacturing jobs (% Factory), 2) a low level of education (% High School Grads), and 3) a highly urban character (% Urban) are important explanatory factors. The agreement measure suggests that this model is rather poor.

large internal movements of population in the United States looking specifically at changes in congressional representation and presidential politics.

Specific Educational Goals: This module will introduce students to four of the five fundamental themes of geographic inquiry: Location, Place, Movement, and Regions. They will learn migration patterns and locate similar and varied life conditions within the United States. They will form regions based on both individual and sets of attributes to gain some sense of place for different sections of the country. The module will also apply the scientific method. Students will propose hypotheses concerning factors underlying a movement pattern, run a simulation model to test the hypotheses, and through feedback from the GIS map and query capabilities of the module, refine their hypotheses to better simulate the push-pull factors governing migration streams.

Nuclear Accident:

General Description: This module will allow students to explore the consequences of a major accident at any nuclear-powered plant in the world. Movement of the resulting radiation "cloud" will be simulated using raster GIS algorithms based on the general circulation of the atmosphere. The "costs" to human populations, agriculture, urban areas and other variables will be computed by GIS overlay.

Specific Educational Goals: Emphasis on Human/Environment Interactions is evident in any study that relates the effects of a technological hazard on natural and cultural environments. Movement, in this case guided by physical forces, is another clear theme as the radiation cloud interacts with precipitation and winds. It is no longer acceptable to assume that the problems of a place on the other side of the globe are not our own. Students will examine directly the dependence we all share on the physical systems of our planet. They will make hypotheses concerning those areas which would be affected by a particular accident based on global wind pattern information, will initiate a simulated accident at that site, and will observe the accuracy of their predictions.

Orienteering:

General Description: A fundamental element of introductory geography is the use of maps. This module will apply the unique storage, random access, and still-frame capabilities of digital video interactive (DVI) technology (Intel 1990) to build a surrogate travel simulation from an extensive database of photographs taken in southwestern Virginia. This module will teach map orientation skills, including the ability to determine one's position on Earth through a map, the location of distant objects in relation to that position, and the ability to use a compass and map to navigate though an unknown area (for a full description of the videodisc-based prototype of this module see Carstensen and Cox 1989, and for the simulation techniques used see Cox 1987).

Specific Educational Goals: This module will illustrate to students the fundamental themes of Location, Movement, and Human-Environment Interaction. The centerpiece of this module is a rather unusual application of location. Instead of locating a distant city, place, or region on a map, the student is placed "at" an unknown location by the simulation and must visually determine the physical characteristics of that location through an interaction with the environment. Once location is successfully established, the student moves through the region via a GIS-based data structure. Success in locating oneself on an abstract rendition of the real world is key to effective map use, whether a topographic, thematic, or highway map. This module will make students more aware of the role of geography in their daily spatial behavior.

Module Tutorials

All modules will carry multimedia tutorials including graphics, text, and video images. The design of each module assumes that the user has little or no background in the subject matter, or in use of the module. Each tutorial will operate as

both an introduction to the content of the module and an introduction to use of the module. The content tutorials will reflect current teaching of the field as exemplified by popular texts. The tutorials will provide concise lessons that could stand alone as useful introductions to the concepts of population change, migration, natural hazards, and position finding, or serve as review if being used in conjunction with a lecture series.

Just as our geographic simulations stress interactive learning, so too must our informational tutorials. Many multimedia presentations are simply lecture presentations presented via computer to a passive student. We aim to create truly interactive, informational tutorials by integrating the simulations into the tutorial presentations. This innovative technique will allow students, while still reading and viewing the tutorial, to run appropriate portions of the simulation to illustrate dynamic concepts more clearly than could a static presentation.

Our initial formative evaluation of the International Population tutorial has pointed out that students are unwilling to expend much effort in learning how to use CAE programs, regardless of whether instructions are presented on-line or on printed handouts. Therefore, whenever instruction on the use of the modules is required, it will be accomplished through use of the programs themselves. A short interactive training session will be built into each program to make students go through a guided tour of all simulation functions.

Some modules will also include a post-simulation review and critique of choices made by the user while running the simulation. These tutorials "after-the-fact" will occur in modules in which the student has made choices that affect the quality of the outcome. The computer log file for each student will support this activity.

Initial Effectiveness and Student Reactions

At present the International Population module is nearly complete. In March 1993, the entire package was used in a small section of Introduction to Human Geography to ascertain its effectiveness as a stand-alone introduction to human population change. The class was divided in half for three 75-minute lecture periods. Twenty-five students (the in-class group) attended lectures, while another 25 students (the *GeoSim* group) worked only in the laboratory to complete an exercise using the *GeoSim* tutorial and simulation. Both groups were allowed the same amount of time to learn the material, had access to the class textbook (Getis, Getis, and Fellman 1991), and took identical examinations on population issues immediately following the experiment.

Examination scores were nearly identical. Of a possible 32 correct answers, the mean number correct was 26.84 for the in-class group and 26.36 for the *GeoSim* group. The in-class group showed a wider variation of scores (standard deviation of 3.9 correct answers) as compared to the *GeoSim* group (standard deviation of 2.7 correct answers), suggesting that the material was more evenly retained using *GeoSim*.

To judge students' opinions of the software, they were asked to fill in a short questionnaire after completing the laboratory exercise. As a summary, they were asked "Was your time well spent in learning about human population change in this manner? Please rate your overall experience with the module (1–not worthwhile, 10–very worthwhile)." Most students saw the benefits of the exercise. The mean overall rating was 7.86 with a range from 3 to 10. According to self reports, the average amount of time spent on the laboratory was 2 hours and 30 minutes, a savings of 1 hour and 15 minutes over the in-class group.

Dissemination of *GeoSim* Modules and Databases

All four modules described here are currently under development. As described above, the first completed version of International Population was used in the classroom during March 1993. Orienteering has a completed prototype which has been used by several classes thus far. Working models of Migration and Political Power and Nuclear Accident are currently near completion, with initial student testing scheduled for the summer and fall of 1993. Databases to support the modules are either complete, nearing completion, or being updated to include data fields from the 1990 census of population and housing. After a year of extensive formative and summative evaluation in classes at Virginia Tech (and parallel testing at a second university), the four modules and all accompanying databases will be available for dissemination to other departments and universities by December 1994. International Population (along with prototype versions of one or two of the other modules) will be available in the fall of 1993. We expect to distribute *GeoSim* by CD-ROM and floppy disc for a nominal distribution fee. Computer network distribution via anonymous FTP on the Internet is currently available from geosim.cs.vt.edu (IP# 128.173.6.111).

Conclusions

GeoSim will promote interactive learning by melding the advantages of GIS and simulation with those of multimedia tutoring. Geographic Information Systems are powerful decision-support tools that provide sophisticated analysis with elaborate query and data display capabilities. Simulation is recognized as having several inherent benefits over more traditional teaching methods: 1) simulation promotes active involvement rather than passive participation (DeBloois 1982), 2) simulation provides immediate feedback on the quality and success of decision-making (Gach 1982), and 3) simulation stresses decision-making and judgment rather than recall of information, promoting analytical skills rather than memorization (Gach 1982).

By adding significant geographic analysis to the initial course in the major, one that is generally offered to non-majors and enrolls over 425,000 students annually nationwide, and by offering the software and databases inexpensively, we expect that *GeoSim* will be widely used. It is our ultimate hope that students from all fields will learn that geography is truly a scientific discipline, not one based only on rote memorization. They will gain experience at geographic analysis early enough in the college curriculum to consider geography an interesting and worthwhile career. Even for those who do not

select geography as a major or career, we believe their future experience with science will be enhanced by exposure to the techniques of geography.

References

America 2000: An educational strategy. 1991. Washington, D.C.: US Government Printing Office.

Bergman and T. McKnight. 1993. *Introduction to geography.* Englewood Cliffs, NJ: Prentice-Hall.

Bettis, N. C. 1990. NAEP releases assessment of geography knowledge. *Perspective,* 18(4):1.

Carstensen, L. W., and A. B. Cox. 1989. Videodiscs and surrogate travel/ the map-environment interface. *Cartographica* 26(3,4):1-21.

Commission of International Education. American Council on Education 1984. *What we don't know can hurt us.* Washington: D.C.: American Council on Education.

Cox, A. B. 1987. *Map position finding performance in a photographically simulated environment* M.S. thesis, Blacksburg, VA: Virginia Polytechnic Institute and State University.

Dallas Times-Herald. 1983. Newspaper sponsored survey of high school students' knowledge of geography.

DeBlij, H. J., and P. O. Muller. 1992. *Geography: Regions and concepts,* Rev. 6th ed., New York: John Wiley and Sons.

DeBloois, M. ed. 1982. Videodisc/microcomputer courseware design. Englewood Cliffs: *Educational Technology Publications.*

Fellman, J., A. Getis and J. Getis. 1992. Human geography landscapes of human activities. Dubuque: Wm. C. Brown.

Gach, S. 1982. When interactive video works. *Video Systems..*

Getis, A., J. Getis, and J. Fellman. 1991. *Introduction to geography.* Dubuque: Wm. C. Brown.

Hardwick, S., and D. Holtgrieve. 1990. *Patterns on our planet: Concepts and themes.* Columbus: Merrill.

Intel. 1990. Down the multimedia road. *Interactivities* Vol. 2(1): 4-5.

Joint Committee on Geographic Education. 1984 Guidelines for geographic education: Elementary and secondary schools. Washington, DC: National Council for Geographic Education and the Association of American Geographers.

NAEP Geography Consensus Project. 1992. Geography assessment framework for the 1994 National Assessment of Educational Progress. Washington, D.C.: U.S. Department of Education, National Assessment Governing Board.

Rubenstein, J. 1992. *An introduction to human geography.* 3rd ed. New York: McMillan.

Shaffer, C. A., L. W. Carstensen, V. F. Miranda, S. K. Kriss, R. W. Morrill, and E. A. Fox. 1991. *Project GeoSim: The first two modules.* Technical Report TR 91-26, Department of Computer Science, Virginia Tech.

Walker, W. J. 1991. Schwendeman's directory of college geography of the United States. Richmond, KY: The Geographical Studies Research Center.

Acknowledgements

We gratefully acknowledge the National Science Foundation (under grant #USE-9155943), the Fund for the Improvement of Post-Secondary Education (FIPSE, under grant #P116B20130), and Virginia Tech for support of our work.

GeoSim software may be downloaded via anonymous FTP from geosim.cs.vt.edu (IP# 128.173.6.111). For more information concerning *GeoSim* modules, contact the authors either using regular mail: Department of Geography, or Department of Computer Science, Virginia Tech, Blacksburg, VA 24061-0115 (Geography) or 24061-0106 (Computer Science), or internet: geosim @ cs.vt.edu.