Geographic Information Systems in the Classroom: Methods and Philosophies

Terry J. Brown and Jon Bryan Burley*

ABSTRACT

Geographic Information Systems (GIS) is a spatial analysis tool that has received increasing interest for natural resource applications. This tool is being employed in the classroom setting to teach students about natural resource management, planning, and design. The tool is still relatively new and educators are interested in learning about how to use this tool in the classroom. Based on GIS classroom experiences from 1972 through 1993, we present our philosophy concerning methods and approaches when teaching spatial applications for environmental management. We suggest that the student maintain real experiences and contact with the landscape through classroom exercises; emphasize contextual issues related to GIS before and after computer modeling; integrate GIS with verbal, written, and graphical skills; and allow flexibility in the modeling topics to be studied. In addition, we discourage the endless memorization of GIS routines and algorithms, rather we stress the experiential act of modeling.

LANDSCAPE PLANNING has been an integral part of landscape architecture curriculums since the turn of the century. One technical skill that evolved with these curriculums was overlay landscape analysis methods, developed by Warren Manning (Manning, 1913; Steinitz et al., 1976), a landscape architect of the early 1900s. This methodology is a spatial process, adopted and embellished by geographers, and popularized by Ian McHarg (McHarg, 1969). Computerized approaches to performing traditional hand-drawn landscape analysis made substantial gains in the 1960s with the availability of the digital computer. Howard T. Fisher, the first director of the Harvard Graduate School of Design's Laboratory of Computer Graphics, and his staff were the first to couple the computer with overlay techniques that allowed the user to do what McHarg did with his hand- drawn overlays (Burrough, 1986). These developments by the Harvard group and many other individuals and teams resulted in the rapid development and acceptance of GIS across natural resource sciences.

As interest in combining GIS and landscape planning increases for natural resource specialists and professionals, individuals often desire to study fundamental pedagogical principles associated with teaching and instructing college students in topics related to GIS and landscape planning. Most of these principles are undocumented beliefs that have relatively few supporting research investigations as evidence, yet these beliefs form the basis of many aspects for curriculums in higher education. Therefore, we desire to present our beliefs and rationales for inspection by colleagues and interested educators. The elaboration concerning a course's structure affords opportunities for others to challenge the beliefs, and adopt meaningful portions of the curriculum, and presents concepts suitable for higher education research projects.

This paper describes the curriculum, philosophic perspectives, and student products related to teaching GIS and landscape planning by examining a college course in the GIS and landscape planning instructional area, taught at the Univ. of Michigan in the landscape architecture program, School of Natural Resources and Environment.

The general goals of the course are to: (i) acquaint students with the important issues, problems, and approaches of landscape planning; (ii) create an awareness and understanding that site and land planning are part of a continuum and are inseparable within the design process; (iii) provide

T.J. Brown, Landscape Architecture, School of Natural Resources & Environment, Univ. of Michigan, Ann Arbor, MI 48109; J.B. Burley, Landscape Architecture, Dep. of Geography, College of Social Science, Michigan State Univ., East Lansing, MI 48824. Received 26 Nov. 1993. *Corresponding author (burleyj@pilot.msu.edu).

Published in J. Nat. Resour. Life Sci. Educ. 25:17–25 (1996).

Abbreviations: GIS, geographic information systems.

an awareness and understanding of how spatial information can be collected, analyzed, then combined to generate maps that allow one to investigate land planning alternatives; and (iv) create an awareness and applied understanding of various landscape planning methods.

Notice that in the goals for the course, computers and GIS are not mentioned. Geographic Information Systems is employed as a tool to accomplish the goals; however, learning GIS is not the prime objective. Concurrently, drawing, writing, public speaking, and mathematical skills are also important operational aspects of the course but are not mentioned in the goals. These skills, along with GIS, play an important role in the course but they are ancillary to the primary goals.

In 1972, Fall term, GRID (Sinton and Steinitz, 1969) was the first computer software program employed in the course, installed to execute on the Univ. of Michigan mainframe computer, an IBM 360 Model 68. GRID is a grid-cell (or raster) mapping program. The data bank developed and used in the course consisted of 1/25 km cells, 4 ha in area, representing parts of four townships in Oakland County, Michigan. Students generally had no computer experience and were taught FORTRAN IV so they could use the GRID program. Data were stored on data cards and analysis routines were initiated with data cards. The process to submit a routine and obtain results often encumbered more than 8 h and required intermediary handling of the printed data by a university staff person. Then in the Winter term of 1977, IMGRID (Sinton, 1977) was initiated, which also ran on the Univ. of Michigan mainframe, an Amdahl 470 V6. This raster program was designed for people having no previous experience with computers. IMGRID'S basic operations are controlled with simple commands that may be used without any knowledge of programming. The data again consisted of 1/25 km grid cells from parts of four townships. Analysis routines were initiated with data cards and by typing commands from a keyboard. Winter term 1984 marked the installation of the GIS MAP ANALYSIS (Tomlin, 1980), again operating on the Univ. of Michigan mainframe, an Amdahl 470 V8. These data were comprised of 1 ha grid cells, from one township in Washtenaw County, Michigan. Analytic routines could be initiated by typing commands from DECwriter or ONTEL terminals connected to the mainframe. Alphanumeric character printed results could often be obtained in 15 min. With each successive installation of a new mapping or GIS program, the student gained greater analytic capability, increased production quality, and greater flexibility to fit student work schedules. However, students were often critical of the perceived limited capabilities of these programs and disappointed in the tremendous amount of work required to generate maps from simple and sometimes coarse spatial models.

Finally, in the Winter term of 1992, MAPII (Pazner et al., 1989) was employed, running on Mac Plus and Mac II computers. The students had their own data diskette containing 31 overlays of a complete township in Washtenaw County, Michigan (Fig. 1). The data consisted of 1 ha cells and each overlay contained 9506 data cells. Maps consisting of gray tone or patterns could be printed in a few minutes and obtained by the students without intermediary handling of the printed data. Students had access to individual comput-

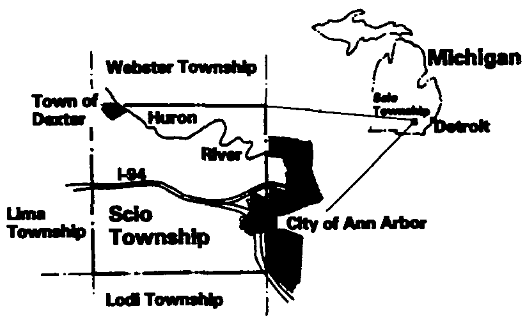

Fig. 1. These maps locate the current study area employed in the classroom.

ing stations and were not dependent on the mainframe environment. The MAPII program contained greater analytic and graphic capabilities than the past programs; however the change was not without costs. While the mainframe rarely lost data, several students each term would lose information through careless diskette handling, data transfer or simply a misplaced diskette. Without backup data diskettes, students could lose any part of or the whole semester's effort.

It is interesting to note that each of these software programs employed in the course are related to each other, with each new program being a different generation, built from previous computer codes. As each new generation of software was introduced, the class was weaned from the university's mainframe computer facilities and eventually no class time was spent on computer mainframe systems or software languages.

DISCUSSION

To facilitate the use of a GIS as a planning tool, the course is organized to address five major components that operationalize the goals of the course:

1. Landscape investigations, Phase 1
2. Landscape planning process, Phase 2
3. GIS analytic tools, Phase 3
4. Landscape analytic models, Phase 4
5. Development of landscape planning guidelines, Phase 5

The course pursues a process model where one develops a program (identify needs, issues, and opportunities), conducts an inventory, proceeds with analysis, and develops solutions based on the analysis. We believe this approach gives context to the techniques and tools, establishing a framework on which to thoughtfully apply GIS. Figure 2 presents the course syllabus illustrating the sequencing of the five phases.

Landscape Investigations (Phase 1)

The first phase of the course pursues the connectivity of the subject matter to other topics rather than simply teaching the technology. Focusing on the technology alone was considered by the course instructors to be a mistake. For example, some GIS instructional models have stressed the technological capabilities of modern tools without providing a basis concerning where the technology originated and why

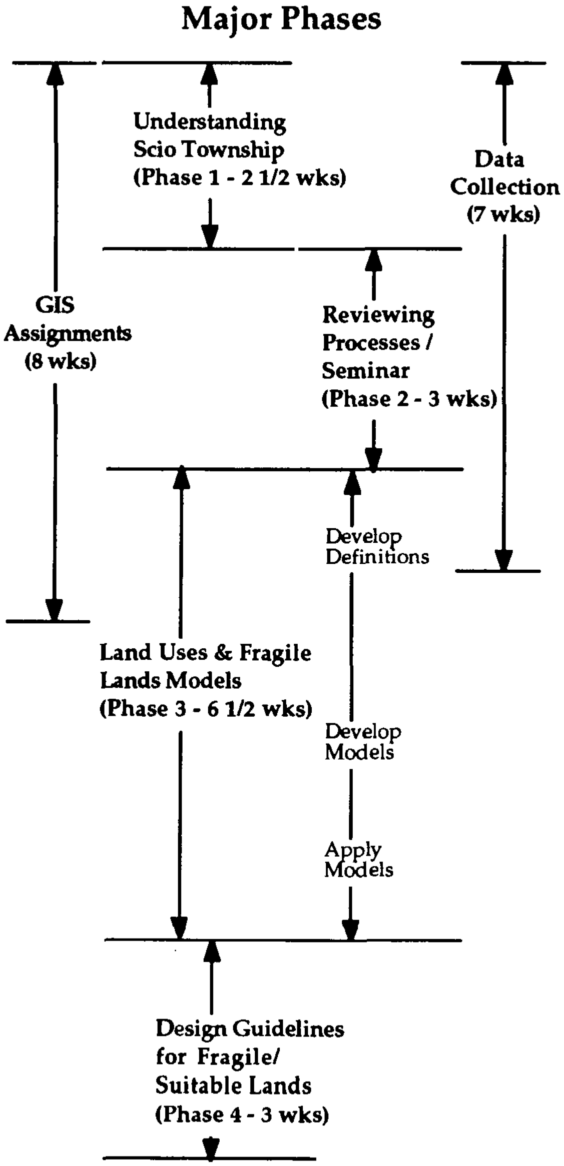

Fig. 2. Course syllabus illustrating the sequencing of the five phases, coordinated with lectures and guest speakers.

someone might use the technology. Therefore, to invoke the instructional curriculum, the first assignment in the course is almost a phenomenological, ethnographic, heuristic approach where students travel and explore a study area with the aid of the camera and video to derive their impressions about the nature of the study area. Student groups present their impressions via multimedia, describing the study area's existing landscape and land uses. Student groups are given a maximum of 30 min to present their impressions.

The exercise is an open assignment; however, each student group, (minimum of three students and a maximum of four students), must fulfill several requirements. First, each group must locate on a base map three or four areas that are particularly important in describing the character of the township. In addition, they must submit three adjectives that describe each area on the base map. Each group must submit two graphic sections they feel best visually describe the study area. One section should depict how humans have influenced the structure of the study area. The second section concentrates on the structure and composition of the physical landscape, excluding man's influence. After the presentations, all graphic materials are available to all students during the term.

This heuristic exploration is valuable because the study area that the students visit will be the same area the students study in the GIS model building. We believe the site visit builds a sense of reality and reduces the probability that the future model building will become a faceless exercise. While computer analysis is helpful, we believe students and professionals must remain in experiential contact with the landscape they are studying.

During the presentation of their impressions, the students often note the changes that have occurred in the landscapes. They notice some resources are not protected or some other resource is not being used wisely. From ad hoc planning and design, they observe developments not fully realizing potential benefits. They describe conflicts between land uses and citizen visions for the area. We believe this exercise builds a sense in the student for the programmatic forces at work within the study area.

Besides building a sense of reality, we believe this first exercise allows students to meet each other, gain some degree of comradeship, and afford the instructors some method of assessing students' current skills and abilities in a nonthreatening learning environment. Student strengths and shortcomings are observed and noted. For example, individuals with weak verbal skills will encounter future opportunities to improve their abilities.

The tone of instructor criticism in this first exercise is essential. We believe that criticism should be in the form of questions to clarify student declarations and ideas. Student discussion should be encouraged. There should be little, if any, emphasis on the correctness of student responses or statements about the technical adequacy of a presentation. Technical failure will be self-evident and since the students are stating their beliefs, there is not necessarily a correct or incorrect answer. A typical question might be, "We noticed no one mentioned the freeway in their presentation. Is the freeway not a substantial element in the study area's landscape?" The purpose of the question is to elicit intellectual response through dialectic methods. While some students may be wondering whether they missed something or if they did something wrong, we believe the tone of the discussion builds student interaction and confidence, demonstrating nonhostile intentions. We also believe that all students should participate in the discussion; meaning while questions may be focused on a particular student, all students are recognized and may contribute to the class discussion.

Landscape Planning Process (Phase 2)

The second phase of the course is associated with the assimilation and synthesis from the current body of literature associated with the landscape planning process. This phase addresses techniques, philosophies, and authorities in landscape planning.

Essentially, there are two tracks one may take with this topic. The first approach is to present lectures, have the students take notes, read literature, and then be evaluated in an exam. The other approach is for groups of students to address a specific topic and present the topic in the form of a seminar and short synopsis paper.

We chose the second approach for one major reason. We believe that memorizing names, dates, and technical terms in a rapidly evolving field may be of limited value. Instead, assembling, assimilating, comprehending, restating, and communicating a set of ideas concerning the landscape planning process will be of greater value to the student. In many respects, we believe that our students who explore the landscape planning process also learn the process of literature exploration and use.

Students work in groups and address topics in one of four areas: landscape classification, map overlays, matrices and checklists, and visual quality. The topics overlap with each other resulting in the students attempting to sort the topics, identify similarities, and note differences. The literature for these topics is quite large. As a team, the students build a resource file and bibliography of papers. To invoke the process, students are presented with a short list of important and selected papers. Each year, students find new sources suitable for inclusion in bibliographies of subsequent landscape planning classes.

During the seminar presentation, each group has 35 min to present their material and answer questions. The presentation is both verbal and visual. Each group is requested to present key authorities, problems in methodology, and analytic opportunities. Students may describe economic feasibility, data collection costs, flexibility, reliability, ease of interpretation, and tips concerning the communication of results. Students also include a short paper, no longer than five pages, and full working bibliography rating the literature according to the following scale:

1. Very useful (in understanding the overall method, stands by itself)
2. Useful (good case study, but not a full description of the method)
3. Limited (useful but needs to be combined with other readings)

The bibliography in this paper lists many of the articles useful in building a base literature set for learning about landscape planning methods and techniques, including Steiner (1991), Kaplan et al. (1989), Taylor et al. (1987), Albert et al. (1986), Westman (1985), Bastedo and Theberge (1983), Rodiek (1978), Fabos and Caswell (1977), Hills (1976), Steinitz et al. (1976), and Lyle and Von Wodlke (1974).

We believe there is an important relationship between the first two phases of the course. The first phase allows students to develop a relatively uninhibited presentation and illuminates possibilities for future presentations. The second phase allows students to actualize their developing ideas. Without this illumination, we believe students may not develop as rapidly in their presentation skills.

For the student presentations, we believe lecturing methods typically used by professors such as 50-min presentations with overheads or the oratory lecturing style, may not always be advantageous or meritorious of duplication. We encourage our students to focus on a message and develop a presentation which enhances that message. When students employ the standard lecturing model, often the presentation is ineffective and loses the audience. We encourage students to break with parochial traditions and treat their presentation as a design project where the presentation may also become a work of art, focused on both verbal and visual communication skills.

Students also learn from phase I that asking questions during presentations is encouraged and this activity builds during the second phase. We believe we have witnessed a successful seminar when the classroom is filled with student discussion in which all sides are congenial. Instructors act only as referees and facilitators enabling timid individuals to present their ideas. We believe it is a major mistake when the professor leads the discussion at the cost of student involvement. From our perspective, a course in landscape planning is not meant to establish the instructors as superior landscape planners and the students as inferior; nor is the primary objective of the course to test the instructor's knowledge base. Rather the course is directed at building student intellectual ability, strengthening the student knowledge base, and developing student technical skills. We believe it is essential that the course instructors take great interest in allowing students to debate their ideas and embellish their thoughts.[1]

This is the first phase in which a paper accompanies the presentation. Although no specific format is dictated for the paper, a five-page limit is strictly enforced. Written and verbal skills are important throughout the course.

Geographic Information Systems Analytic Tools (Phase 3)

Concurrent to the landscape investigation and planning process assignments, students are presented with a series of lectures and given assignments related to developing GIS skills. The students use an existing database to explore the analytic capabilities of a GIS software package and are presented with the opportunity to collect data to build an additional overlay to add to the existing data set. Each student is given a diskette containing the data and the student purchases a copy of the software program and tutorial booklet (Pazner et al., 1989).

Each GIS software assignment introduces a series of concepts to the student in a relatively flexible manner. For example, the recode command may be introduced, where the student must recode values of a map and assign new values creating a new map overlay. However, the selection of the overlay which the student wishes to recode is the student's choice.

Each GIS assignment successively builds upon skills developed in the preceding assignment. We believe that to learn a skill, the skill must be applied to accomplish another task. For example, an assignment teaching the recode command enables the student to explore the fundamentals of the command, but when the student applies the recode com-

[1] We feel that instructors must have a great deal of confidence and maturity to teach with these methods. Instructors with less self-confidence may believe that it is their obligation to establish a strict social order and demonstrated professor dominance. However, if one is truly interested in student learning and less interested in social hierarchy, one might allow some chaos. There is ample opportunity throughout the class to convey information in the traditional lecture format and experimental formats.

Table 1. List of commands and application of previous commands during the GIS skill development phase of the course.

Assignment	New commands and new tools	Previous commands and tools
1	Display & Printing Tools	
2	Recode, Compute Slice	Display & Printing Tools
3	Cross, Combine Cover, Average	Recode, & Compute, Display & Printing Tools
4	Spread & Radiate	Recode, Compute, Cross, Combine, & Cover, Display & Printing Tools
5	Scan & Clump	Recode; Compute, Cross, Combine, Cover, & Spread Display & Printing Tools
6	Editing Tools	Recode

mand to another task, we feel the student begins to develop a greater cognitive ability with the command.[2] Table 1 lists the assignments, the new commands explored, and the old commands studied in previous assignments.

Notice that not all possible GIS program routines are presented in the assignments. While there are many other commands and options, the fundamental set of tools is rather simple. Other commands are easily applied or studied as required by the direction the student pursues in an assignment. We believe there is no urgent need to present every command in detail at the expense of other course objectives. While there are certainly advanced applications related to the commands and the student has the flexibility to pursue these advanced applications, we feel that in an introductory course, the full exploration of each and every command would be unnecessary.[3]

In GIS, many of the commands often strike students as esoteric. For example, why would one want to apply a round moving window algorithm to an overlay? To aid the student in developing reasons for applying particular commands, each assignment is structured so the student can select that command and apply the command in the assignment. One student may envision an erosion control application for applying the scan command; while another student may envision a housing suitability application.

The required products for each assignment include printed output and a written narrative (Fig. 3) describing what the student was attempting to accomplish. The narrative identifies the commands employed, a description of the options employed for each command, and a description of the expected outcome. We believe emphasis should be placed on understanding the command so the student may correctly anticipate expected algorithm results; the actual printed output for these assignments is less important. All too often GIS novices and even some professionals apply GIS algorithms without actually confirming the results. We suggest to students to take sample locations within the study area

Narrative - Assignment 2

Recode Luagr91 Assigning 3 To 7 To 9 (agriculture recode)

Recode Lutrans Assigning 2 to 1 assigning 1to 2 through 9 (recode lutrans)

Combine «agriculture recode» with «recode lutrans» (Assign. 2)

Fig. 3. This graphic (*a*) and typed response (*b*) present the spatial results and intent of a student for a GIS assignment.

and check the results against what they expected, a manual check of 6 to 12 cells within a 9000 cell study area is an invaluable experience. Often the student interprets the expected results of the algorithm quite differently than the actual command performs the routine. Software manuals are not always clear, we have found errors in algorithms, and simply because a computer is used does not make the results 100% correct. A manual check of only a few cells can give students a tremendous boost of confidence in their understanding of the software.

The last assignment allows the students to build an overlay. Students are assigned discrete areas in an overlay and code their assigned areas. They use aerial photographs, maps, and site visits to build their coded maps. Then the areas are merged to create a new overlay. Problems often arise; students who did not work closely with other students who had adjoining coding areas often have mismatched data. All matching errors must be corrected.

The assignment presents important lessons in data building. While one can lecture on the hazards of site classifica-

[2]Parallel educational examples exist in mathematics. To learn algebra, geometry, and trigonometry, it is often helpful to advance to calculus where one must apply algebra, geometry, and trigonometry. Consequently, if one wishes to learn calculus, it is helpful to pursue engineering applications of calculus.

[3]Parallel examples also exist in art courses where the student is presented with a basic set of techniques for paint, markers, and pencil. However, the full set of techniques are rarely presented. Instead, the student is given opportunities to explore the existing set and then develop specialized techniques.

Table 2. Typical topic choices presented to students, from which spatial model types are developed.

Land uses

- Estate residential—1 dwelling unit per hectare, on-site septic tank, domestic wells for water
- Rural residential—2.5 dwelling units per hectare, on-site septic tank, domestic wells for water
- Suburban residential—5 to 10 dwelling units per hectare, on-site septic tank or fully serviced public sanitary sewer, on-site wells or fully serviced public water
- Mobile home—17.5 units per hectare maximum, sewered or package system, detached dwelling units, minimum 6 ha of development
- General commercial—2 to 4 ha in size, public sewer and water, within 6 min driving time from existing housing
- Active recreation—soccer/football field complex, softball/baseball field complex, intensive development and managed for mass public use, potential septic tank and well water
- Passive recreation—trails, camping, interpretive center, archery, rifle, trap, skeet ranges, fishing, boating, canoeing, extensively developed for outdoor recreation
- Conservation—critical land set aside for protection of resources, limited development, public land
- Office park—single firm or multi-clients, modern architecture and site development, corporate headquarters, professional office park, package or public utilities services
- Landfill/recycling center—service study area or larger vicinity, determine disposal of by-products, landfill needs

Fragile lands

- Soil erosion—identify susceptible areas
- Wildlife habitat—select wildlife type for study and identify critical/potential habitat areas
- Vegetation—select vegetation type for study and identify critical/potential restoration/preservation areas
- Groundwater quality/supply—protect groundwater resources from contamination and/or degradation due to development or land use activities
- Surface water/creekshed quality—identify areas most susceptible to surface water pollution or areas with flooding hazards
- Visual quality—identify significant visual quality areas suitable for protection
- Rural character—identify significant rural character suitable for protection
- Agricultural land—identify important agricultural lands suitable for protection
- Noise quality—identify sensitive areas to noise pollution or identify areas with adverse noise pollution that require attenuation

tion and decision rules, we have discovered that students seem to develop a great understanding of data building by constructing a data set. In addition, students seem to develop a greater appreciation for existing data when they have to create one or two new overlays.

Sometimes instructors make the mistake of requiring students to build the complete set of overlays from scratch. While building a complete set can be an illuminating process leading to some important research studies, the process may be too time consuming for an introductory college course where emphasis should be placed on cognitive skills not man-power efforts. The student should develop an awareness of this arena, and not necessarily a complete applied understanding of the many issues concerning spatial databases.

Landscape Analytic Models (Phase 4)

In our opinion, gaining the experience of developing and applying a spatial model is an important feature of the course. This phase in the educational process focuses on the development and organization of specific planning data to evaluate the study area for suitable land use locations and assessment of fragile lands.

Each student is allowed to pick a specific land use or fragile land type (Table 2) and build a spatial model to identify suitable sites for development or conservation. By allowing the students to select their land use or fragile land, students have the opportunity to address a topic that is of interest to them. Usually the students are a diverse group with a broad set of preferences and aspirations. Some students envision working in a professional office and having a client that will develop the landscape; other individuals may have a preference for a specific fragile land. In addition, by giving students some flexibility and requiring classroom presentation, the students as a group are exposed to a wide range of land development approaches and conservation issues. We also believe that unhealthy competition is reduced because students are not attempting to generate solutions to the same question; instead students are allowed to explore their own issue and report to the class. We believe competition exists between students to excel in their particular study topic but not at the cost of another student's grade.

To begin this process, we require students to define their land use or fragile land by carefully identifying its characteristics as precisely as possible. A one-page paper is required. However, there is no correct or incorrect student response for the definition. Instead, the definition exercise is an attempt to assist students in clearly stating their construct of the topic. For example, an individual addressing wildlife issues may define fragile land as habitat for red-eyed vireo; a student studying groundwater issues may state the identification and protection of aquifer recharge areas is the focus of the study. Requiring students to define their land use or fragile land allows them the opportunity to focus their understanding of the topics and develop a program associated with the topics. Again, a right or wrong answer is not sought, rather, we, as instructors, are concerned whether students can specifically and clearly describe their topic to their peers.

After defining their land-use or fragile system, the students begin developing the assessment model. During the model development we recommend that students avoid employing computer modeling terminology. Instead, we request students build the ideal conceptual model to assess their landscape study area. During the actual application of the model, the ideal model can be refined; however, in the ideal model development, we do not want students to be inhibited by the constraints of the computer algorithms or existing data bank; nor do we want the algorithms to guide the modeling process. Rather we want each student to devise a model and then to discover approaches to accomplish the aims of the model. The same is true for the existing data bank. The student is encouraged to think beyond the data at hand. We believe many creative ideas come forth in the use and creation of data for the model with this approach. As the models are developed, students employ techniques studied during the landscape planning process portion of the course. In addition, students develop diagrammatic models of the analysis process.

Finally, the student applies the model. We stipulate that the modeling process must be applied to every cell in the study area; otherwise students employ modeling routines that are so detailed that there is only time for the student to apply the model to a few hectares. Students operationalize their models, revising as necessary and often discovering creative approaches to accomplishing the tasks associated in their ideal model.

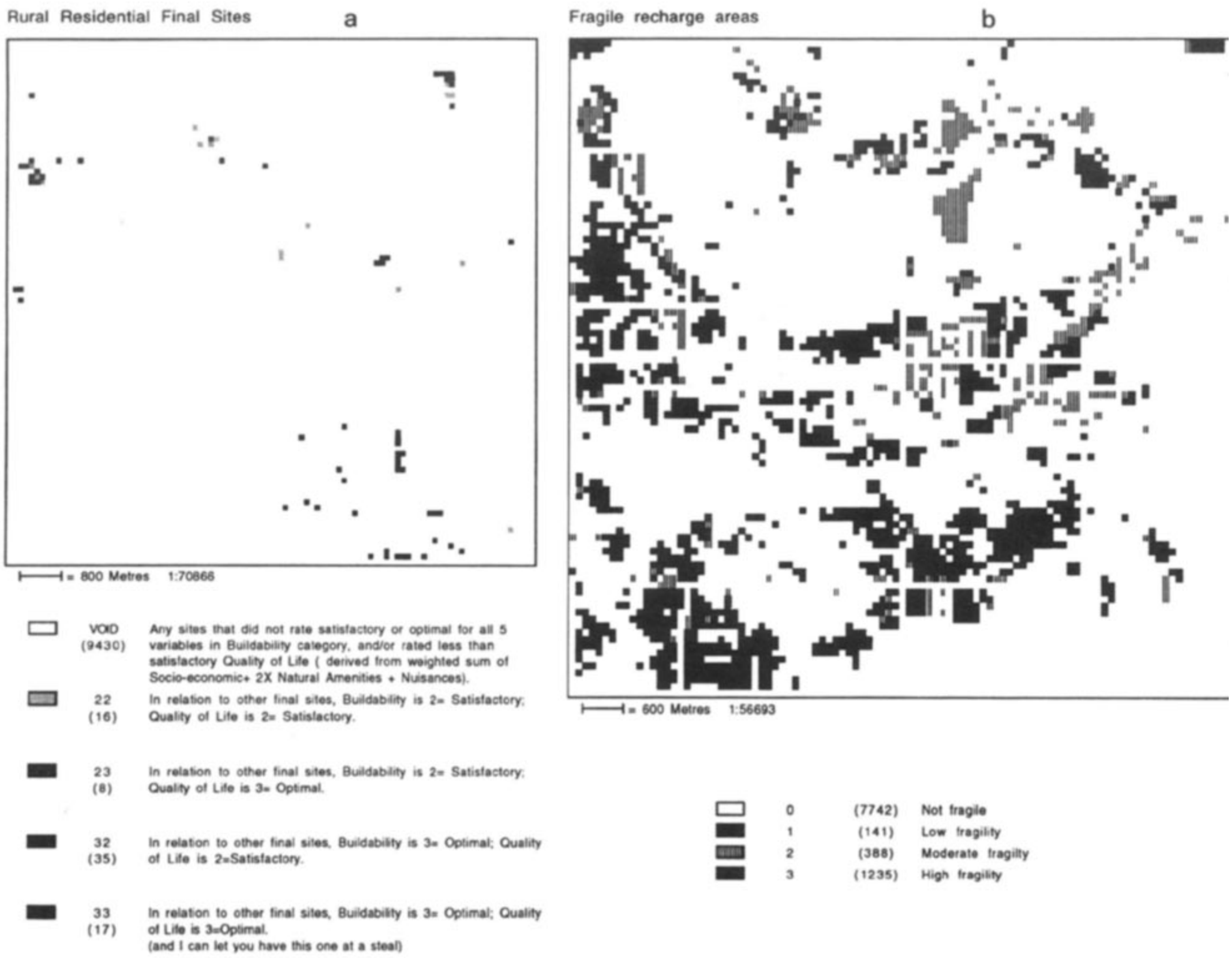

Fig. 4. (*a*) Results from one land-use model identifying parcels suitable for rural residential housing and (*b*) one fragile land model indicating sensitive aquifer recharge areas.

During this modeling application, we strongly urge the students to check their results. Did they obtain overlays that make sense? Do the overlays produce reasonable results? This emphasis is especially important with the advent of GIS modeling on personal computers. In the past, computer results generated on mainframes limited student desire to generate output; often only the initial input overlays and final results were printed. However, today students may print all initial and intermediate overlays, and final results, meaning that 50 maps or more can be printed. It appears that when the technology is extremely simple to use, there is an overload of generated material. Presenting 50 maps may be substituting quantity for quality. To assist in analytic interpretation of the model, we urge students to carefully assess each map generated in the GIS process. For example, in one class a student had blindly applied the model and found there were no suitable sites in the study area; the model may have been extremely restrictive. By assessing each intermediary, the student can quickly identify mistakes and stages in the process where the model is too restrictive.

As the students apply their models, we do not emphasize the absolute correctness of the model, but rather we emphasize "are they doing what they said they would do?" We take this approach because in many respects the students are primarily building heuristic, nonempirical models with occasionally some empirical equation imbedded within a small portion of the model. As in role playing, we assume that the student is the expert and that the models are based on scientific, governmental, and citizen consensus.[4]

During the modeling exercise, students are free to conduct nonautomated segments. This means that the students can employ other noncomputer spatial methods resulting in spatial information and then code the information to be applied to the computer modeling process. Conversely, a computer-generated map may be employed using nonautomated techniques. However, the final expected result is a map that rates the whole study area and divides the land-

[4] We believe that most GIS models, especially models where suitability, and fragility are applied, comprise primarily a family of maps that ask the questions, "Where is the best land?" and "Where is the most important land?" These types of questions are value laden, because the answer depends on the values one ascribes to. While one can develop empirical equations to predict water runoff, soil erosion, wildlife populations, and estimated traffic volumes, in the modeling process these empirical equations only supply partial answers and do not definitely describe, "What should we do?"

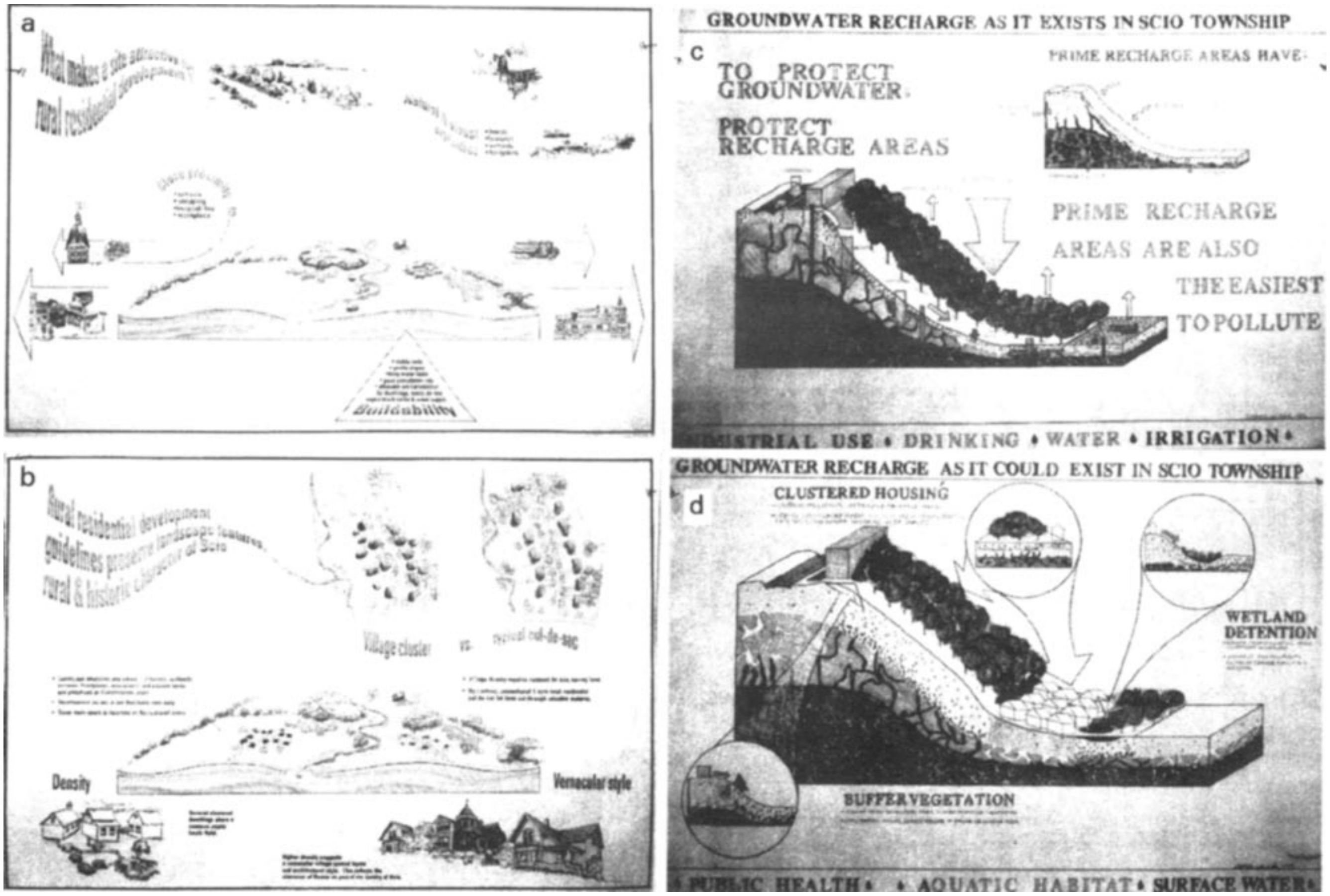

Fig. 5. Example of student guidelines (*a, b*) for a housing land-use and (*c, d*) for groundwater recharge areas, a fragile land.

scape into highly suitable to not suitable sites, or into highly fragile to not fragile locations.

During this exercise, we are not concerned with developing future experts in each topic; rather, we are concerned with students having the opportunity to develop and apply a model so that in the future they may have the GIS modeling skills and creative ability to address whatever topic they encounter. Nevertheless, the models that are developed by the students are often state-of-the-art models, meritorious of publication, and some students obtain employment in the subject area related to their specific model's topic. Figure 4 presents an example of student results.

Development of Landscape Planning Guidelines (Phase 5)

We believe that translating spatial models into meaningful decisions about the structuring of the environment can be a difficult but essential task. On numerous occasions we have witnessed superior spatial analysis "die on the vine" because translating the analysis into meaningful design and planning recommendations were not achieved. Therefore, the last portion of the landscape planning course addresses the development of spatial analysis into a set of discrete design guidelines that transform the findings of the spatial analysis into planning recommendations suitable for implementation. For example, a student who has identified an area of fragile lands will develop a set of guidelines to protect the resource.

The course up to this point has dealt primarily with the written ideas, verbal expressions, or computer terminology, except when visuals are used during presentations. During this final phase, the instructors emphasize the graphic skills of landscape architects. One of the most important things that landscape architects can do is to use their graphic skills to help people visualize the physical outcomes of planning recommendations. Through the use of various media and views, landscape planners can visually describe the "sense of place" that their planning recommendations will create. During this phase, students are asked to use a creative design approach to graphically communicate to a site developer how to save what needs to be saved and build what needs to be built. The intent of the guidelines is not to develop a complete set of design guidelines, but to portray key concepts in the protection or development of the space.

To accomplish this task, each student produces two graphic panels (Fig. 5). One panel presents the landscape under study, its problems/opportunities, and why both must be understood in relationship to future development (Fig. 5a) or understanding a fragile land (Fig. 5c). The second panel illustrates expectations and recommendations for a land use (Fig. 5b) on the selected site with its associated fragile lands or how the fragile lands (Fig. 5d) would be managed and preserved for future generations.

Other Features

There are other features of the course that do not result in student products, but we feel are important to include in the classroom setting. The most important feature is the inclusion of a broad interdisciplinary base of ideas and concepts. Selected academic and professional individuals present lectures on specific topics including: local governmental concerns, site classification, soils as indicators, landscape ecology, landscape restoration, and alternatives in spatial modeling. The value in these lectures/seminars is the interaction of students and guest lecturer. Students openly and freely ask questions, discuss concepts, and develop ideas, and are also presented with the opportunity to establish contacts with faculty members and local professionals.

The landscape planning course sets a foundation for further spatial analysis applications. In other coursework, students must complete an individual practicum or interdisciplinary project. The landscape planning course facilitates the accomplishment of this requirement by incorporating the use of digital scanning technology and graphic software programs for advanced landscape planning applications.

CONCLUSION

We have developed a set of principles that articulate our beliefs associated with the organization of the landscape planning course. These principles may be helpful to other individuals desiring to establish a course addressing the use of GIS and related topics.

1. Maintain real experiential contact with landscapes under study.
2. Emphasize contextual process. Applying GIS requires preparatory work and post-modeling applications.
3. Avoid being seduced by technology; employ GIS technology that is useful in teaching. This technology may not necessarily be the most powerful, complex, number-crunching software package available.
4. Allow students to integrate GIS technology with verbal, written, and graphical skills.
5. Empower students with flexibility in topics to be studied. Provide an educational setting where students can share their diverse experiences, enabling the whole group to observe and compare across a broad set of issues.
6. Avoid endless lists of GIS program routines, names, dates, and analytic techniques. The act of "doing" is much more important than remembering everything.
7. Provide the intellectual course structure and facilitate communication to allow the students to grow within that structure.

Despite the belief that GIS models may be predominantly heuristic, this does not mean that "anything goes." Instead, GIS modeling is an art and science where alternatives should be carefully assessed and the methodology associated with a model should be clearly stated. Because GIS modeling is so heuristically based and can be contested, investigators should present their methodology openly and not employ the "black box" model.

REFERENCES

Albert, D.A., S.R. Denton, and B.V. Barnes. 1986. Regional landscape ecosystems of Michigan. School of Natural Resources, Univ. of Michigan, Ann Arbor.

Bastedo, J.D., and J.B. Theberge. 1983. An appraisal of interdisciplinary resource surveys. Landscape Plan. 10:317–334.

Burrough, P.A. 1986. Principles of geographical information systems for land resources assessment. Oxford Univ. Press, New York.

Fabos, J.G., and S.J. Caswell. 1977. Composite landscape assessment: Assessment procedures for special resources, hazards, and development suitability; part II of the metropolitan landscape planning model (METLAND). Univ. of Massachusetts Agric. Exp. Stn. Res. Bull. 637.

Hills, G.A. 1976. An integrated iterative holistic approach to ecosystem classification. p. 201–218. *In* J. Thie and G. Ironside (ed.) Ecological (biophysical) land classification in Canada/ Classification aecologique (biophysique) du territoire au Canada. Proc., 1st Meet., Petawawa, ON. 25–28 May 1976. Canada Committee on Ecological (Biophysical) Land Classification. Lands Directorate, Environment, Penawana, ON, Canada.

Kaplan, R., S. Kaplan, and T. Brown. 1989. Environmental preference: A comparison of four domains of predictors. Environ. Behavior 21:509–530.

Lyle, J., and M. Von Wodlke. 1977. An information system for environmental planning. J. Am. Inst. Planners 40(1):257–271.

Manning, W. 1913. The Billerica town plan. Landscape Arch. 3:106–118.

McHarg, I.L. 1969. Design with nature. Doubleday/Natural History Press, New York.

Pazner, M., K.C. Kirby, and N. Thies. 1989. MAP II: reference manual and tutorial: A geographic information system for the Macintosh. John Wiley & Sons, New York.

Rodiek, J.E. 1978. Landscape analysis- A technique for ecosystem assessment and land use planning. Landscape Plan. 5:27–44.

Sinton, D.F. 1977. The user's guide to IMGRID: An information system for grid cell data structures. Dep. of Landscape Architecture, Graduate School of Design, Harvard Univ., Cambridge, MA.

Sinton, D.F., and C.F. Steinitz. 1969. GRID: A user's manual. Laboratory for Computer Graphics and Spatial Analysis. Graduate School of Design, Harvard Univ., Cambridge, MA.

Steiner, F. 1991. The development of performance requirements in Medford Township, New Jersey. p. 152–155. *In* The living landscape: An ecological approach to landscape planning. McGraw-Hill, New York.

Steinitz, C.F., P. Parker, and L. Jordan. 1976. Hand-drawn overlays: Their history and prospective uses. Landscape Arch. 66:444–455.

Taylor, J.G., E.H. Zube, and J.L. Sells. 1987. Landscape assessment and perception research methods. p. 361–407. *In* R.B. Bechtel et al. (ed.) Methods in environmental and behavioral research. Van Nostrand Reinhold, New York.

Tomlin, C.D. 1980. The map analysis package (draft manual). Yale School of Forestry and Environ. Studies, New Haven, CT.

Westman, W.E. 1985. Quantitative approaches. p. 131–167. *In* Ecology, impact assessment and environmental planning. J. Wiley Interscience, New York.◆