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Integrating GIS Education with Training: A Project-Oriented Approach

X. Mara Chen

Geographic information systems (GIS) were first introduced in geography as a fundamental research tool. The need for geographers to accept and embrace GIS technology stemmed largely from the fact that GIS offered tremendous potential as an analytical system in a large research and information management environment. As a result most GIS courses were offered within graduate programs (Walsh 1992). In the early 1980s fewer than 10 geography programs in the U.S. offered GIS courses (Morgan and Fleury 1993). But GIS “fever” started to sweep geography in the late 1980s, and the demand to offer GIS education in geography programs grew rapidly across a wide range of educational institutions. Teaching institutions responded to the rapidly growing job market for well-trained GIS geography graduates by quickly introducing GIS courses into their curricula. A simple analysis of the data presented in the 1996-97 AAG Guide to Programs in Geography (Association of American Geographers 1996) shows that 90% of graduate programs and 78% of undergraduate programs have a GIS component as part of their geography curricula.

As more departments add GIS into their curricula in response to the growing demand of the public and private sectors, concern over GIS education has increased: What should be taught? and How do we teach GIS? As for what to teach, the National Center for Geographic Information and Analysis (NCGIA) established a 75-unit, content-based GIS core curriculum (Kemp and Goodchild 1991), which provides a fundamental outline of the substance of teaching GIS in higher education. As for how to teach GIS, uncertainty remains. Very little discussion has taken place on how to make the connection between content-based GIS education and skill-oriented technical training. King (1991) expresses concern that students may spend too much time mastering a major GIS software package and too little time on other geography courses. Kemp et al. (1992) suggest that undergraduate GIS courses should emphasize education in concepts over training in software use. In recent years GIS experts have come to agree upon the importance of the training component in GIS education. Some believe that GIS education can be best achieved through lectures about conceptual issues combined with hands-on training (Walsh 1992, Nellis 1994). Sui (1995) argues that the selection of GIS education methodology should depend upon two aspects: teaching about GIS and teaching with GIS. In his argument, teaching about GIS should concentrate on GIS technology with an instructional focus on training, and teaching with GIS should focus on GIS applications with instructional emphasis on content education.

Abstract

As more geography departments add geographic information systems (GIS) to their curricula in response to the growing demand of the market-place, concern has been mounting over the content and methodology of GIS education. No consensus exists on how to make the connection between GIS education and GIS training at the undergraduate level. This article argues that hands-on, project-oriented teaching can offer an ideal approach to integrating GIS education and training. It presents a project-oriented GIS teaching experience as an instructional paradigm that can be used to ensure the balance between conceptual GIS learning and software-based, hands-on training in undergraduate GIS education.

Key Words: undergraduate GIS education and training, hands-on active learning, project-oriented teaching, undergraduate research

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Furthermore, Foote (1994, 1997a) states that an integrated problem-solving approach to teaching GIS actually sharpened students’ analytical reasoning abilities. Aangeenbrug (1997) states that the use of project-oriented GIS education and training offers a link between the employer and the user.

Clearly, in confronting the challenges in GIS education, no consensus has been reached on how to make the connection between GIS education and training. Moreover, institutions have different resources, course offerings, and pedagogical objectives. Large research institutions have well-equipped computer labs and well-trained graduate students available for teaching or assisting GIS labs. At small teaching institutions, GIS education and training often is a one-person shop with limited resources. Although much progress has recently been made in balancing GIS education and training at geography departments with graduate programs, very little discussion has taken place on how to meet these challenges at the undergraduate level.

This article argues that conceptual knowledge paralleled with project-oriented, hands-on training can offer an ideal bridge between GIS education and training at the undergraduate level. It presents a project-oriented GIS teaching experience at Salisbury State University (SSU) and further discusses the benefits of project-oriented teaching. The article also outlines how to successfully implement this approach to enhance students’ understanding of underlying conceptual principles and practical applications of GIS technology.

WHAT IS PROJECT-ORIENTED GIS TEACHING?

Project-oriented teaching is not a new concept. It has been practiced for years in education, psychology, and landscape architecture. Reinfrid (1996) stated that geography is especially suited for project-oriented teaching. The problem is that the term project in the project-oriented GIS teaching is not clearly defined; project means different things to different people, and different programs have different project designs. More departments granting graduate degrees offer an array of GIS courses, and upper-level courses have application-oriented GIS training components, with graduate students providing lab assistance. But the situation is very different for undergraduate geography departments, where application- and project-oriented teaching becomes very challenging, even logistically. This article argues that undergraduate GIS education and training, especially in programs with a limited GIS course offering, should promote a project-oriented teaching approach. A GIS class project should be carried out through hands-on training, should carry out the complete project. This enables students to experience all aspects of a real-world GIS project and to appreciate the team effort required and a feeling of individual accomplishment. Students also learn about the multidisciplinary nature of problem solving and the customization of research designs through spatial data processing and alternative analytical techniques.

Unlike practical GIS training done to produce GIS technicians, the purpose of project-oriented GIS training is to promote undergraduate students’ critical thinking and problem-solving skills. The project-oriented approach requires students to apply their GIS knowledge to solve a geographic problem by using a commercial GIS software package, and should be carried out through hands-on software training. In the training process, lab exercises should be designed in a coherent sequence to implement various stages of a complete project. The implementation process (shown in Figure 1) follows a top-down approach and includes five sequential execution stages that are mutually dependent, as indicated by double-direction arrows.

Project planning and design is the first and most critical step in the process. In this stage the instructor explains GIS project planning and design. Students are asked to discuss and identify a project that they are interested in that can be completed in a semester using available resources. Students are required to outline the questions for which they seek answers, to define project implementation strategies, and to understand and negotiate their collective and individual responsibilities throughout the implementation process. The goals of this stage are to identify students’ research interest and objectives, to develop students’ decision-making skills, to improve students’ research design and project planning abilities, and to foster their teamwork and interpersonal communication skills. As Burns and Henderson (1989) argue, students must first know geography in order to know and use GIS. Foote (1997a) states that interesting research problems helped capture students’ attention and expand their intellectual horizons. Thus, project planning and design require students to use their
knowledge of geography, spatial perspectives, and research interests in defining a GIS class project. To most undergraduates the class project is their first real-world GIS research application. The planning and design stage offers students a classroom forum to exchange ideas on the conceptual design and practical implementation procedures of the project.

Once the project is clearly defined, hands-on technical training can begin. From the second to the fourth stage, students are asked to develop a digital geographic database, to query the database, and to perform spatial analyses to find answers for their posed questions or seek information to justify their arguments. The objectives of these stages are to teach students hands-on technical skills in data searching, preprocessing and input, digitizing, editing, database development, data query, and geographic data analysis. Students should be informed of the availability of various data (e.g., DLG, TIGER files, DEM, digital aerial photographs, and images of the study area). During the training process an instructor should demonstrate the necessary commands and how to use them, instead of focusing on all the details of the hardware and software. The underlying guideline is that geography undergraduates should be well-trained GIS users and problem solvers. It is important that students be informed users—they should drive the software through insightful hypotheses and clear statements of purposes, not let the software control the process through blind acceptance of defaults and programmed command streams. The training should provide students with an opportunity to better understand and apply GIS concepts and principles. Equally important, students should be strongly encouraged to experiment independently at their own pace and to learn professional responsibility (e.g., productivity vs. quality) from their mistakes. For example, students who work more slowly are allowed to put in extra hours to complete the required work, and those who learn and work faster are encouraged to experiment with alternative methods to solving the same problem.

In the last stage, students are required to review their class project, to reflect upon what they have accomplished, to record the results of spatial analyses and associated database queries, and to document their project in a final report. The purpose of

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**Figure 1. Implementation flow chart of project-oriented GIS training.**
this stage is to encourage students to reflect upon the learning process through critical thinking and research writing. Students are asked to put everything together to answer the posed questions, to justify their implementation procedures, and to analyze whether they achieved the intended goals of the project. If they do not achieve the goals they are asked to discuss the problems and to explain what lessons they learned. Writing is critical to a higher level of thinking, and it is an essential step in completing the cycle of GIS learning. Sui (1995) presented a GIS education pyramid: data, information, knowledge, and intelligence. One effective way of checking students' journey on their way up the pyramid is to let them document their learning process and present their geographic analyses.

AN EXAMPLE: A GIS CLASS PROJECT

The Department of Geography and Regional Planning at SSU offers two GIS courses for geography majors: a 3-credit Introduction to GIS course and a 4-credit Advanced GIS course. Students in the advanced course have successfully completed an introductory GIS course, which is taught as a content-oriented course with a lab component. The lab sessions in the introductory course are typically modular-exercise based, and each modular project can be carried out independently. Students are exposed to simple software packages such as IDRISI and Atlas GIS, but they are not required to complete a project. They are exposed to the concepts of a GIS database and database management, but they are not asked to create a GIS database for a real application. To expand students' learning, the advanced course provides them with hands-on technical training and a focused education on both the conceptual issues and the application aspects of a GIS project using PC ARC/INFO (version 3.5.1) and ArcView (version 3.0a) software (products of Environmental Systems Research Institute Inc.). Given the sophistication and complexity of the software, basic ARC/INFO training itself is not a simple task. Instead of pure technical training on ARC/INFO modules and commands, the course follows a project-oriented teaching approach to integrate GIS education and training. In the end, students are expected to have hands-on working knowledge of fundamental ARC/INFO utilities in Arcshell, Arcedit, Table/INFO, and spatial overlay analyses, as well as ArcView functions (not including ArcView Spatial Analyst and Network Analyst extensions).

In the spring semester of 1997, the students chose to do a change-detection study of the SSU main campus. The project was chosen because of the students' familiarity with the study site and because of the rapid changes to the campus over the past two decades. But more importantly, the students believed that GIS was an ideal tool to map changes to the campus and to present a clear picture of how the university had responded to the rapid growth to meet students' needs, especially for parking. Together, they discussed and agreed upon what base map, map projection, and coordinate system to use. Based on the availability of large-scale campus base maps, students set forth to map the land use changes on the campus between 1973 and 1996. The major questions they decided to answer were: How much change has occurred in parking? in vegetation? in the number and floor space of buildings? They also wanted to determine if the changes were parallel to the growth in the student population. Once the questions were identified, the land use classes were defined. The campus was classified into five general land use categories: building, parking, sidewalk and pavement, vegetation, and recreation.

The SSU campus base maps of 1973 and 1996, obtained from the university physical plant office, were engineering prints at the scale 1:1,200, with no coordinate grids or specified projection system. Before digitizing, the students needed to establish control points and to perform a data generalization on the base maps. For example, sidewalks and driveways were treated as either line or polygon features, parking lots were treated as polygon features, and extra lines were added to close off parking lots from driveways. As for registering the maps in the context of a real-world coordinate system, control points were determined through cross-registering the base maps with USGS 7.5 Quad topo maps and 1996 aerial photographs of campus. Students learned that geocoding was not a simple process of tracing from original base maps, but depended on the objective of a GIS project. In the digitizing stage, the students were divided into four subgroups in order to save time. Students within a subgroup were asked to digitize the same portion of the campus map. This approach was designed to promote their independent skills and their cooperative group-learning skills at the same time. After digitizing, the maps from corresponding subgroups were combined to create two complete digital campus maps of 1973 and 1996. Subsequently, students worked independently and at their own pace most
of the time (i.e., they had the maximum flexibility in terms of lab hours and individual learning strategies). They edited the digitized map, geocoded the attribute data, and performed queries and spatial analyses using ARC/INFO software. After that, they were taught to use ArcView software. They then generated a final map and summary table using ArcView software and wrote a project report.

Overall, they followed the implementation sequence shown in Figure 1, advancing to the next stage after completing the work of the prior stage. The process, however, was not a one-way linear flow (e.g., some students had to go back to the editing process when they found errors during the labeling stage).

Students arrived at the following conclusions from the GIS query/overlay analyses.

1. The change in parking area has been proportional to the growth in student population, contrary to students’ common perception. However, more commuting students might have added to the growing parking problem.
2. The proportion of buildings has kept up with the increase in student population. However, the study did not provide enough information on the functionality of the buildings (e.g., the number of classrooms and labs) in relation to the growth of the campus since the students did not have time to develop an extensive relational database.
3. Total vegetation cover on campus has greatly decreased and individual vegetation areas have become smaller as a result of construction of new buildings and parking areas.

Some students even suggested that GIS should be used as a decision-making tool in the future planning of the university in order to curb the decrease in vegetation and to preserve the campus landscape, which has achieved national arboretum status. Clearly, students were able to address the temporal change issue from a broad geographic perspective.

**DISCUSSION: WHY PROJECT-ORIENTED GIS TEACHING?**

GIS projects give students a better sense of the benefits offered by technology, and the potential value goes beyond understanding the technical aspects of GIS (Taketa 1994). GIS technology enhances our ability to understand spatial processes and conceptual geographic ideas (Nellis 1994). To best achieve the goals of undergraduate GIS education, well-rounded GIS graduates need both education and training (Green and McEwen 1990). An understanding of general GIS concepts allows students to place GIS in a broader geography framework, but this understanding can be greatly enhanced through authentic applications (Kemp et al. 1992). Undergraduate education benefits from working on a research project (Moore and Longley 1988, Taketa 1994, Reinfried 1996). Moreover, project-oriented learning emphasizes hands-on training and therefore enhances students' competitiveness in the marketplace. Employers continue to demand students who have some hands-on working knowledge of GIS using a commercial software package (Rogerson 1992). According to a GIS World survey (Wikle 1994), nearly 83% of respondents indicated that expertise with a commercial GIS package was an important part of undergraduate GIS education.

To look further into the issue, GIS can be broadly defined as a computer-based information system. By its very nature, GIS education and training may demand that we pay close attention to the educational trends of the related technical disciplines (e.g., computer sciences, information technology, software engineering). Edward (1996) points out that, in information system instructions, being a spectator in the information age is not the same as being a hands-on user. Pomberger (1993) calls for more emphasis on project-oriented education in software engineering. Smith (1996) advocates a shift from lecture-centered instruction to lab-centered teaching in computer science and argues that teaching should follow a process approach that teaches students "learning to learn."

From the experience at SSU, project-oriented teaching has provided students with balanced GIS education and training. A real-world project defined and completed by the students clearly enhanced their understanding of GIS technology and its applications. The successful completion of the project indicates that the students gained a broader understanding of GIS issues. Based on my observations throughout the process, their understanding is not only on the aspects of project planning, data abstraction and generalization, data input and data quality, spatial relationships of geographic entities, database and spatial analysis, and map production; but also on the importance of indi-
vidual responsibility and cooperative teamwork. Consistent with Rogerson's (1992) comments that commercial software plays a significant role in GIS education, a project-oriented approach demonstrated that students could gain fundamental problem-solving skills by applying their geographic knowledge using commercial GIS software. Comments from the students themselves are important indicators of the merit of this approach. The only negative comments arose from frustrations concerning the amount of work involved and inadequate computer processing power (slow speed and crashes). Some positive comments include the following.

- The project helped students gain a better understanding of using GIS to answer spatial questions.
- The hands-on approach in combination with the theoretical classroom background gave them a solid understanding of GIS technology.
- The project provided students with an opportunity to obtain a set of skills that they will need in the real world, such as critical thinking, problem solving and project management, interpersonal communication, as well as research writing.
- Two graduate students and five students in GIS-related jobs later commented that the project-oriented training helped them with their graduate study or in their employment.
- The project gave students a chance to apply their knowledge, which has kept them more eager to learn.

From my experience the importance and benefits of this teaching approach should be greatly emphasized, but many challenges exist. This approach requires considerable commitment from the instructor prior to as well as during the course, particularly if no graduate assistant is available. It also demands that all students have adequate geography background and computer skills. The implementation process is very time consuming because the instructor needs to guide students on a multitude of aspects of GIS, such as how to manage the project, how to apply conceptual GIS methods, and how to use a special software package. Because of these reasons, project-based GIS teaching was not widely used in many geography programs as of the early 1990s (Kemp et al. 1992). Also, some schools provide a simplified approach and the class projects do not include all the components defined here. For example, some projects only cover data input and transformation or database query and report writing (see Taketa 1994). Indeed, the project-oriented GIS teaching approach defined in this article may not be workable for every GIS course due to its complexity. But it should be given more priority in upper-level GIS education at four-year undergraduate institutions. In four-year institutions without this approach, undergraduates cannot gain the needed exposure to real-world GIS applications and the necessary vocational and technical skills. Some may argue that undergraduates can gain hands-on GIS training through internships, but too often employers do not know much about GIS themselves and are not in a good position to teach interns.

In summary, the benefits resulting from this approach far outweigh the challenges. With appropriate planning, the difficulties can be largely overcome. Based on the SSU experience in the past two years, the strategies listed below can be used to improve the teaching-and-learning efficiency of the project-oriented approach.

- The applications and issues of GIS should define the scope of technical training, rather than the other way around. Train students how to learn and use the necessary tools (modules and commands) needed for a specific application, but not all the commands of a particular GIS software package. The bottom line is that training in any specific GIS package is a continuing learning experience with its endless new upgrades. But through this approach, students can grasp the basic methodology so that they become confident of lifelong self-learning.
- Students should be given a general time frame for completing certain stages in the project, but within this time frame they should be allowed to work at their own pace. According to the seven principles for good practice in undergraduate education (Chickering and Gamson 1987), the process should respect diverse talents and ways of learning. Students are less afraid of making mistakes in their attempts to experiment and explore.
- The course objectives can be better achieved through a sound curriculum
design. This approach would be best suited to a two-course sequence with four contact lab hours per week. Lab size should not exceed the number of computer stations, and more importantly, not exceed the effective interaction capacity. This allows each student to have his/her own computer station and promotes good interactions between student and instructor.

- A “black-box patch” should be used to cover technical details when they become time consuming or too hard for students. The black-box patch is a technical operation completed by an instructor for a GIS class project. For example, in our class project the selection of tic points for the campus base maps and the determination of the coordinates were done ahead of time by using aerial photos and topo maps at different scales.

- Lecture topics should be arranged in a parallel pace with the class project implementation to enhance the linkage between conceptual issues and technical practicals. Lectures should be presented in an interactive, inquiry-oriented manner. Case studies and previous class projects should be embedded into lectures.

- The Internet should be used to deliver GIS course materials. Foote’s Virtual Geography Department Project3 has demonstrated the great potential for geography faculties to use the Web in teaching GIS. Through the use of this powerful tool, students can spend most of their time actively participating in classroom discussions instead of taking notes, and they can access the Web site for interactive tutoring when they like (Foote 1997b, Chen 1997, Xu 1997). At the beginning, establishing an extensive set of courseware can be time consuming for an instructor, but with new technology, such as a smart classroom computer projection system, the task will become less demanding.

CONCLUSION

The information era demands the integration of GIS education and training. Geography students should have well-rounded conceptual knowledge and hands-on GIS technical skills. The GIS education experience at SSU has shown that students’ understanding of GIS technology and interpersonal skills can be greatly enhanced through implementing a GIS project. Although there is no universal consensus on how to teach GIS, a great need for a continued discussion and review of GIS education will always exist (Goodchild and Kemp 1992). A well-planned, project-oriented approach presents an ideal bridge between education and training for undergraduate GIS education. This approach provides a physical setting for active inquiry-based learning and learning opportunities of cooperative group work. It has been documented that active learning and group work in higher education could challenge students to learn and empower them to think (Anderson 1997, Burkill 1997). A project-oriented teaching approach renders a realistic solution to balancing undergraduate GIS education and training.

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NOTES

1 Of course, not all GIS components are the same—some departments offer a broad array of GIS courses and allied techniques while other departments offer but a single course in a limited cluster of courses.

2 A sample map output from the GIS class project is available on the Web at henson1.ssu.edu/~xmchen/gncur/g415-97.htm.

3 Foote’s Virtual Geography Department Project can be found on the Web at www.utexas.edu/depts/grg/virtidept/contents.html

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