METHODS AND TECHNIQUES

Teaching GIS in Geography*

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Although numerous courses in geographic information systems (GIS) have been introduced into the geography curriculum over the past few years, there has been remarkably little debate over the issues involved. This paper first discusses the arguments for geography as an appropriate disciplinary setting for GIS teaching at the undergraduate level. This is followed by a discussion of the nature of GIS courses and their appropriate place in the undergraduate geography curriculum. The final section of the paper describes the NCGIA Core Curriculum project and examines its significance in this broader context. **Key Words: GIS, geographic education.**

Introduction

While there has been some debate over the value of geographic information systems (GIS) to geography in general (Abler 1988; Dobson 1983, and subsequent commentaries in *The Professional Geographer;* Jordan 1988, and subsequent correspondence in the *AAG Newsletter*), there has been somewhat less debate over the place of GIS in the geography curriculum. One notable exception is a series of presentations at a special session of the Canadian Association of Geographers in 1985, subsequently published in *The Operational Geographer.* However, only a subset of these (Goodchild 1985; Muller 1985; Poiker 1985) specifically addressed the needs of geography, the remainder being more concerned with the general issue of GIS education. The same is true of the series of meetings on GIS and Higher Education held at Ohio State University in 1988, 1989, and 1990 and at the University of South Florida in 1991, and of the handful of additional articles on GIS education that have appeared in the literature (Nyerges and Chrisman 1989; Unwin and Dale 1990).

The purpose of this paper is to explore arguments for the teaching of GIS within geography at the undergraduate level, the implications of these arguments for the objectives, structure, and content of GIS courses, and their positioning within the course sequence of an undergraduate geography curriculum. Many of these issues were debated during the development and evaluation of the *NCGIA Core Curriculum in GIS* recently completed by the National Center for Geographic Information and Analysis (Goodchild and Kemp 1990), and the paper concludes with a review of the curriculum and the processes used in its development.

GIS and Geography

The case for teaching GIS within the geography higher education curriculum rests on several propositions regarding the general significance of GIS to geography, some widely accepted and some controversial. They are presented in this section as four separate arguments: geography as the home discipline for GIS; GIS as a collection of marketable skills; GIS as enabling technology for science; and geographic information as an intellectual theme within geography.

Geography as the Home Discipline

Of the four arguments, this is perhaps the weakest from the discipline's viewpoint. GIS has developed as a multidisciplinary field with no single home, as a consortium of photogrammetry, cartography, spatial statistics, spatial analysis, computer science, engineering, remote sensing, etc. None of these fields has any particular claim to ownership, although all make useful contributions. But multidisciplinary fields inevitably fall through the academic cracks; cooperation through conferences, journals, and organizations is comparatively easy in research activities but much more difficult in education. If higher education is to supply

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the growing employment market with well-trained graduates equipped with an appropriate range of skills, GIS needs a "home discipline" in order that the necessary specialized curricula and instructional methods can be developed and nurtured.

Morrison (1991) argues that geography, with its traditional view of itself as an integrating discipline and its focus on spatial phenomena, is uniquely suited as the home discipline of GIS. But while there may be some agreement with this sentiment within the GIS community in general, the weakness of this argument stems from questions about geography's own willingness and ability to play the role. Jordan's comments (Jordan 1988) clearly demonstrate this reluctance on the part of some geographers to embrace GIS as a contribution to the intellectual core of the discipline, and several recent editorials (Openshaw 1991; Taylor and Overton 1991; Taylor 1990; Goodchild 1991) have added to the debate.

Marketable Skills

There is a rapidly growing market for both new and traditional geographical skills in the GIS industry. GIS software vendors, public and private agencies with GIS installations, and GIS consulting companies have all hired significant numbers of geography graduates in the past few years, and demand is growing as employers recognize the particular value of the geographer's perspective and mix of skills. A great many geography departments have responded to this demand by quickly introducing GIS courses. Thus, GIS has emerged alongside statistics, cartography, surveying, photogrammetry, and remote sensing as a skill area that competes for a place in the geography undergraduate curriculum.

GIS as Enabling Technology for Science

The largest markets for GIS technology currently lie in resource management, the utilities, and local government (for a comprehensive view of the GIS industry see GIS World Inc. 1991), where the primary focus is on geographic information management rather than geographic analysis. There appears, in fact, to be a growing tension in the industry between the large market in information management and the comparatively small but crucial role of GIS in supporting scientific analysis and modeling. Abler (1988) has described the potential of GIS as a tool to support scientific inquiry in geography, and, more generally, in all disciplines that work with geographically referenced information. On the other hand, the value of any such scientific tool is extremely difficult to document, particularly as measured by specific insights gained through the use of the tool that would not have been obtained otherwise. It would be as difficult, for example, to identify GIS's contribution to theory in this sense as it would be to find instances of theory that owes its origins to the use of regression.

From a teaching perspective, the enabling technology argument suggests that GIS should be an integral part of the geography curriculum because of its role as a tool for geographical research. This puts it in competition with all such tools, and begs the question of how we judge the importance of one tool against another. It may be more appropriate for us to teach GIS than word processing, since one is unique to geography and the other generic, but what about statistical packages, for example? Should the competition be judged on frequency of use, or some notion of necessity or uniqueness? Despite its attractions and the essentially geographical nature of GIS, the enabling technology argument seems a weak basis for curriculum design precisely because of the difficulty of making an objective choice between an enormous variety of tools useful for geography.

Geographic Information as an Intellectual Theme

Despite the growing strength of the industry and widespread interest, GIS remains difficult to define. Is it a technology, a set of applications, an approach to analysis and decision-making, or a database? What constitutes "GIS research" (Craig 1989; Maguire 1990; Masser 1990; NCGIA 1989)? Goodchild (1990) has argued that what should hold the GIS community together, particularly at the research level, is a common interest in the generic issues that surround the technology and impede and affect its use. Geographic information has unique characteristics, and its collection, compilation, and analysis present unique problems. The reality represented by geographic information is frequently continuous and always infinitely complex and, therefore, must be discretized, abstracted, generalized, or interpreted for subsequent management and analysis. A variety of alternative data models can be used as bases for discretization. Moreover, geographic information is multidimensional: items of data can be accessed through a two- or three-dimensional spatial key, or through the attributes of objects.

To pursue the argument a little further, the various disciplines and fields that deal with geographical information share a common interest in a set of generic issues that together constitute a science of geographic information. Mark (1990) has argued that GIS has relevance to each of Pattison's four traditional paradigms of geography (Pattison 1964): Man-Land, Earth Science, Area Studies, and Spatial. But the emergence of GIS has suggested an additional theme underlying and contributing to each of these, and composed of the generic issues of geographical information: its capture, compilation, accuracy, display, analysis, etc.

In our view, these issues of geographic information that surround the effective use of GIS technology provide the strongest of the four arguments presented here and the one that should guide the incorporation of GIS into the undergraduate geography curriculum. Issues that have always been implicit in working with geographic information, such as accuracy or display, become explicit within the structure imposed by a digital data handling system. The designer of a GIS database must have an understanding of geography to choose between alternative data models or discretizations, to determine appropriate levels of accuracy, to assess uncertainty, and to display the results effectively. Since a GIS database provides the user with a structured and interpreted view of geographical reality, the uncertainty in data must be modeled and described; the structure of data must be represented in the database by implementing theories of space and spatial cognition (Frank and Mark 1991; Gatrell 1983); and principles of cartographic design must be made explicit in display processes. In a university geography program, these generic issues of geographical information science seem much more important to us than the specifics of a given geographic information system. Together they provide a useful distinction between training in the technology, and education about its concepts, applications and significance.

Teaching GIS

In view of the continuing demand for GIS graduates and the level of sophistication and complexity of many GIS applications, it is inevitable that GIS will be taught somewhere in many universities' programs. At the moment, a majority of the academic departments teaching GIS are departments of geography (Morgan 1990). This section examines the different objectives that can be established for GIS courses, considers where these courses can be placed in an undergraduate geography curriculum, and ends with a discussion of appropriate prerequisites.

GIS Course Objectives

There are at least two dimensions to consider when setting objectives for GIS courses. Perhaps the most basic is that represented by the fundamentally different objectives of education and training (Green and McEwen 1990; Kuennecke 1988; Nyerges 1989; Unwin et al. 1990). Education focuses on the principles and conceptual issues which surround GIS, while training emphasizes the technical skills necessary to operate specific GIS packages. While we have already argued in favor of an education in the key concepts of GIS, few would disagree that a well-rounded GIS graduate needs both education and training (Green and McEwen 1990). An understanding of general concepts allows the student to place GIS specifics in a broader framework, but this understanding is greatly enhanced by working on authentic applications. Training might be sufficient for students looking only for an entry-level position in the workplace, but an emphasis on education is more compatible with the objectives of a university and would be more appropriate for students planning to concentrate on applications and research.

A second dimension to consider is the balance between technical issues and applications. On the one hand it is important to learn about GIS technology, and the hardware, data structures, and algorithms that underlie it. On the other hand it may be more important to learn about working with GIS technology, and the issues that arise in implementing GIS within an organization, or in developing GIS analysis procedures in support of research.

Figure 1 illustrates how these two dimensions are related to specializations within the GIS workplace. For many entry-level positions, training needs to be emphasized along with a mix of technical and applications issues. A focus on the educational and applications perspectives would be more appropriate for graduates entering fields of applied research. System designers would emphasize technical content, and also need to be well educated in theoretical aspects of programming. Those using GIS to support research or to solve real-world problems would need a concentration on applications. Somewhere in the middle we might find the system manager who must be familiar with both technical and applied issues, as well as with implementation and management strategies.

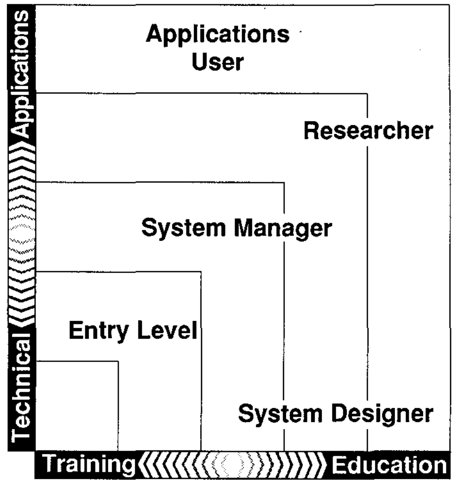

Figure 1: *Two dimensions of GIS specialties.*

GIS in the Geography Program

Given these possible emphases and needs, there are a number of ways in which the teaching of GIS can be incorporated into existing geography programs. To begin, we need to consider whether GIS should be introduced early in the curriculum or be reserved for more advanced students. If it is introduced early, there is little time for students to develop fundamental skills in areas which provide important background knowledge for GIS, including cartography, computer science, statistics, and spatial analysis. Teaching GIS in the later years of the program allows students to gather prerequisites, but cuts short the time available to apply their knowledge of GIS to problem-solving in their particular area of interest.

Several types of introductory courses in GIS are possible. Each plays a different role in addressing the needs of GIS students and occupies a different niche in the overall structure of courses within a geography program. A broad overview of GIS concepts would be the most consistent with our earlier discussion of the arguments for teaching GIS in geography. This course would be placed early in the program, perhaps late in the first year or early in the second, and would support a collection of more advanced and specialized courses. In a paper presented at the 1990 AAG Annual Meetings, Coulson (1990) identifies four "universal geographic tools": cartography, remote sensing and interpretation, GIS, and quantitative methods. He argues that a familiarity with these tools is important to all geographers, regardless of their particular subdiscipline. To provide this knowledge, Coulson proposes a year-long "foundations course," aimed at second-year students, which would introduce concepts that are common to some or all of these tools (e.g., scale and resolution, map projections) and which are often redundantly taught in each specific introductory course. By gathering these into a single course, students would be taught these fundamental concepts once and later courses would have more time to cover advanced material.

Goodchild (1985) goes further in arguing that because a spatial database can be viewed as a model of geographic information, a course in GIS concepts can provide a basic framework for Coulson's "universal geographic tools." He proposes an introductory course in GIS, with an emphasis on the core concepts of a science of geographic information, to be followed by a branching out into courses in remote sensing, cartography, spatial analysis, and the specifics of GIS technology and applications. This structure would emphasize the unique character of geographic information that underlies all geographic data handling technologies.

In practice, GIS is often introduced later in a student's program of study, often as an additional skill or technique and with emphasis on the technical and analytical issues involved in the storage, manipulation, and display of geographic information. Goodchild (1985) has called this the "leaf on the tree" model, emphasizing the way GIS has often been tacked onto existing offerings. All too often this approach has led to the dropping of other skill courses, notably spatial analysis and quantitative methods, to make room in a crowded curriculum, as a deciduous discipline tries to keep up with changing fashion. Heywood (1990) comments on the parallels between GIS and the earlier introduction of spatial analysis courses in the 1960s. Too often, quantitative methods were seen as isolated skills to be acquired by geography students, rather than as tools to be integrated into all aspects of geographical investigation. GIS may well fall into the same trap if it is institutionalized as a specialty and fails to find a role for itself in supporting the traditional, substantive subfields of geography (for an example of the integration of GIS into teaching in economic geography see Dodson 1991a). Such essential skills must surely be located in the core of the curriculum, not on the periphery.

If there is indeed a "zero sum game" in technical courses offering marketable skills, such that new techniques can be introduced only if old ones are eliminated, then the implications for GIS are profound. On the one hand, most definitions of GIS emphasize the importance of analysis and support for decision-making as the primary objectives of the technology, while on the other hand, many authors have commented on the relatively simplistic nature of many current GIS applications (Burrough 1986; Cowen 1988; Openshaw 1987; Star and Estes 1990). It would be tragic if the introduction of GIS into the curriculum were accompanied by a simultaneous loss of courses in spatial analysis or cartography.

Structuring GIS Courses

Lectures or Labs?

In the university environment, there are two primary means for presenting computer-related subject matter: lectures and laboratory exercises. The lecture approach is suitable for presenting theoretical issues in a linear, structured format, while the laboratory environment is less rigorously structured and is also suitable for providing training. Most GIS courses take advantage of both approaches: lectures convey the general concepts and labs reinforce these concepts with hands-on applications. However, it is possible to base a course entirely on exercises or real-world applications in the GIS laboratory. Here, theoretical aspects are presented only when the issues emerge within the context of the laboratory work. Lecture-only approaches are also used, particularly in more advanced courses or where suitable laboratory equipment is simply unavailable.

Synchronization of lecture and lab components is a difficult issue. Should the structure of the lecture outline determine the content and sequence of individual lab exercises, or should the theory needed to learn and intelligently use the laboratory software determine the order in which lectures are presented? Or can the two be fully independent? To make this question more complex, while a lecture can easily be confined to a single topic, a lab exercise, especially one demonstrating an application, will usually encompass several topics. In addition, in order to function in the lab, students must learn the purely mechanical aspects of operating the system hardware and software. This in itself can be a formidable task given the complexity of some commercial GIS packages and can absorb much of the available laboratory time. In statistics courses, it is often argued that manual processing of data is preferable to computer processing, at least initially, because it leads to a greater appreciation for the principles involved, and avoids the distracting influences of computer technology, and a similar argument can be made against lab exercises in GIS. In our view, based on the arguments presented earlier in this paper, the role of labs in an undergraduate GIS course in geography should be to support and illustrate the concepts presented in the lectures as effectively as possible.

Determining Course Content

Although GIS is a comparatively new area, there have already been several attempts to identify the contents of GIS curricula. Some of the results are more complete and immediately useful than others. In this section, we consider several of the ways in which the content and structure of GIS courses have been defined.

In reviewing these different approaches it is important to recognize that they vary considerably according to the intended scope of the curriculum. At one extreme are approaches to defining *macrocurricula*, or general plans for entire programs. The other extreme addresses *microcurricula*, or detailed plans for individual instructional units directed at specific groups of students (Armstrong 1989). The order in which topics are identified provides another variation. In a *top-down approach*, known in education circles as the "behavioral" approach (Armstrong 1989), the knowledge and skills needed by a student for entry into the work force or for advanced courses are identified. These terminal conditions are then translated into the specific topics to be taught. The *bottom-up* approach begins by identifying the component parts of the entire subject area. Curriculum development then focuses on building connections between these topics so that the student completes his or her education with a set of related skills, and with knowledge that is readily adaptable to a wide range of situations.

While each of the following projects or activities has provided input to the development of GIS curricula at various levels of detail, they are not, of course, mutually exclusive. Therefore, while we recognize that many of these activities are complementary, we feel that it is useful to examine each individually as a technique for curriculum development.

Marketplace Needs Surveys. Using a truly behavioral approach to the macrocurriculum, content definition begins with a survey of the marketplace to determine the knowledge and skills required by successful GIS practitioners. A panel discussion at the AAG Annual Meeting in Toronto in 1990 considered the qualities desired in the ideal GIS professional, and the need for graduates with strong problem solving skills was a recurring theme. Willis and Nutter (1990) and GIS World Inc. (1990) describe two formal surveys of the GIS job marketplace that have been conducted to provide input to the design of GIS education programs. An intelligent merging of such expert opinions with the objectives of a university education would provide valuable input to anyone planning a GIS program.

University Curricula. Nyerges and Chrisman (1989) provide a useful bottom-up perspective on GIS macrocurriculum development by considering the range of cartography and GIS skills that should be taught to students in a four-year geography program. Using a conceptual framework relating topics to depth of coverage, they develop a comprehensive design for the introduction and development of an integrated cartography and GIS curriculum. In terms of our earlier discussion, the curriculum is notable in not similarly integrating GIS with geographic analysis and systematic courses, although Nyerges and Chrisman recognize this as desirable.

Tutorials and Demonstrators. GISTutor (Raper and Green 1989) represents an entirely different bottom-up approach to course content. Developed initially in the Macintosh Hypercard environment, GISTutor allows a student to explore a broad range of topics from line intersection algorithms to database query. Students can select their own route through the "cards" (screens) of information, and cleverly designed animated segments are included to show the computational steps in GIS processes.

While there is little comparison between the model curriculum of Nyerges and Chrisman and the GISTutor, both projects have resulted in the identification of topics that are seen to be important in GIS education. Aside from the very different scopes (micro versus macro), the projects are substantially different in structure. While the model curriculum focuses much attention on the topic sequence and the depth to which each must be covered, the GISTutor allows students substantial freedom in the selection, sequencing and depth of the topics chosen for review, within constraints set by the designer.

Software Training Programs. From an entirely different perspective, very rigid microcurriculum projects designed along behavioral lines can be seen in the software training programs developed by various commercial GIS vendors. The specific terminal skills and knowledge required by students who will be operating the given software and hardware determine the limited range of topics that must be covered, and as a result these programs are often weak in theoretical and conceptual content. However, vendors are increasingly recognizing the importance of more general concepts and have begun incorporating them into their training sessions. The ARC/INFO tutorial workbook *Understanding GIS, The ARC/INFO Method* is a good example of this trend (ESRI 1990).

Textbooks. Instructors often look to textbooks for authoritative guidance on course content in a bottom-up approach to both micro- and macrocurriculum development. This has been difficult in GIS to date because of the lack of appropriate texts, particularly in geography, although the situation is improving rapidly. While textbooks necessarily force a degree of logical sequencing of topics, it is often easy to vary the sequence and selection of chapters to fit specific course objectives.

Projects. GIS teaching can be based entirely on hands-on projects. This technique has not been widely used in geography, but is common in landscape architecture and environmental design programs (Tomlin 1990). Project-oriented instruction does not begin with a clearly defined list of topics, but instead the list evolves as the project progresses. Instruction under these conditions can be very demanding for the student and for the instructor, and requires a clear recognition of the range of theoretical and conceptual knowledge that students should acquire during the project and some insight into the sequence in which these principles are best acquired. This approach is perhaps neither top-down nor bottom-up but serendipitous, since the process of defining content must be intuitive and continuously evolving. Sequencing will be defined both by the mechanics of the project and by more conceptual course objectives.

Lecture Outlines. Finally, course content can be designed as a sequence of semi-independent units more or less equivalent to individual lectures of standard duration. This is the approach chosen by the NCGIA for its Core Curriculum project. It has a number of advantages, not the least of which is its familiarity to all academics. It is readily understood and easy to implement. In fact, we chose this approach for the Core Curriculum because of our desire to develop materials that would be modular, and thus readily adaptable by a wide range of GIS instructors. A textbook would not have provided this immediate applicability. Definition of curriculum content through a set of lecture notes is a bottom-up approach to microcurriculum development

Sequencing

Once the objectives, content, and educational approach of the course have been defined, implementation by whatever means requires attention to the sequencing of topics. Some topics might be identified as more fundamental than others, but we have already pointed out that it is not easy to identify the fundamental topics of GIS. Moreover it is not clear that fundamental topics should necessarily be presented first. Sequencing can follow at least two opposing strategies, in a manner similar to the top-down/bottom-up dichotomy presented above. One strategy holds that fundamental principles must be presented first so that the more complex ones can build upon this knowledge, while the alternative begins with a superficial introduction to the complex whole in order to motivate interest in the various component parts. Another strategy follows the natural sequence of tasks in an applied GIS project, beginning with database creation and moving to processing, analysis, and presentation of results. This sequence is commonly followed in GIS training programs (ESRI 1990). The arguments presented earlier in this paper suggest that for undergraduate GIS courses the most appropriate sequence is a short superficial introduction, followed by a progression from simple to complex fundamental principles.

The NCGIA Core Curriculum

In its solicitation for a National Center for Geographic Information and Analysis (NSF 1987), the National Science Foundation recognized that one of the major impediments to the adoption of GIS technology was a shortage of trained professionals. In its proposal to NSF, the Santa Barbara/Buffalo/Maine consortium (University of California, Santa Barbara; State University of New York at Buffalo; University of Maine) argued that a readily adaptable set of teaching materials could have a rapid and significant impact on GIS education. The *Core Curriculum in GIS* was developed over a two-year period following the announcement of the NCGIA award in August 1988. An initial outline for a one-year course sequence was developed in a series of discussions with the GIS community, and some 35 GIS educators in the United States, Canada and the United Kingdom eventually contributed material. A draft version was evaluated and tested at over 100 sites in the 1989–90 academic year, and a revised version was released for general distribution in July 1990. For a detailed description of the development and evaluation of the Core Curriculum, see Kemp and Goodchild (1991a and b). By late 1991, over 750 copies of the three volume, 1000+ page document had been distributed to universities, government agencies, and GIS vendors and consultants around the world.

Design of the Core Curriculum

Given the objective stated above, we chose the lecture format for the Core Curriculum in order to provide (1) a means for rapid dissemination and adoption, (2) a common format for organizing a broad range of diverse topics relevant to the study of GIS, and (3) a structured outline that could be easily modified according to local conditions and preferences. The resulting product consists of detailed outlines and support materials (handouts, readings, slides, and review questions) for 75 lectures organized into three "courses." Supporting laboratory materials are described in a separate series of publications (Dodson 1991b; Dodson, et. al. 1991; Veregin 1991).

The Core Curriculum in Geography

Preparation of the Core Curriculum focused on providing a generic set of materials for teaching GIS in any discipline. Although the editors of the document and many of its original contributors are geographers, we expended considerable effort to ensure that we included a broad range of materials that would be of interest to educators outside of our discipline. Now that the project has been completed and its results acquired by educators in disciplines as diverse as marine science, landscape architecture and civil engineering, we have been able to re-examine our efforts from a geographical perspective. This has been aided by discussions at several Core Curriculum User Group meetings and GIS education workshops, and by comments received on the materials themselves.

The project has produced a number of important impacts on the GIS community in geography. By beginning with an assumption that GIS education is both valuable and necessary, it has presented a "strawman" and allowed discussions to focus on questions of content rather than on the abstract value of an ill-defined subject. With the potential scope and content of GIS courses more clearly articulated, the geography community is now better equipped to debate the broader issues. Is GIS an academic subject, and does it indeed constitute part of a "new" geography? What parts of a general GIS curriculum are important to geography, and where does each topic fit into a geography program? Whatever its faults, the widespread distribution of the Core Curriculum should be a useful basis for debate on some of these issues within the discipline.

This progression of issues can be seen within a framework of innovation adoption. In the first stage, the geographic community recognized the rapid growth of GIS in the user community and began to examine the role of the subject within the discipline. Having recognized its importance, academics then needed to learn about GIS and to examine questions of content and implementation of courses. Now we have reached the early part of the stage of maturity when we begin to think more deeply about pedagogic questions. Discussion of these important questions can only serve to increase the quality of GIS instruction and to improve our degree of satisfaction with our students' education.

Conclusion

The basic premise of this paper is that GIS instruction has been introduced into geography programs in response to a rapidly expanding demand, but without any clear consensus on its place in the geography curriculum, its content, or the appropriate pedagogic approach. Many of the more detailed issues of content, sequence, and approach can be resolved through a clarification of course objectives, particularly in choosing an appropriate balance between education and training, and between technology (learning about GIS) and application (learning to work with GIS). But the more fundamental issues that drive course objectives can only be resolved through the development of a consensus, particularly on the relationship between geography and the diverse set of topics that fall more or less under the GIS umbrella.

Some of the dimensions of the relationship between geography as a discipline and GIS have been discussed in this paper, and we have argued strongly in favor of one—that geography should emphasize the generic issues that arise in working with geographic information and its unique ability as a discipline to focus on them. This may be a controversial position, as it is not obviously compatible with any of the four traditional paradigms of geography. This argument leads to certain conclusions: that GIS courses in undergraduate geography should emphasize education in concepts over training in hardware and software; that these concepts are better taught early in the program; that the conceptual content of lectures should drive the practical content of laboratory exercises; and that course content should progress from simpler to more complex concepts. The final section of the paper described the NCGIA Core Curriculum project, and discussed its potential as a common basis for debate on these issues within the discipline, not only on the desirable content of a GIS course in geography, but also on the relationship between that course and the wider aims of an undergraduate geography program. We see the strength of the GIS industry and its implications for employment of geography graduates as a unique opportunity for rejuvenation of the geography curriculum. We have argued that many of the issues of geographic information that surround GIS applications, and that are so essential to GIS education, are old and familiar issues to geographers, although they occur more starkly and objectively in the digital context. This argument seems to us to be the one that should guide the implementation of GIS courses in geography above all others. ■

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