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TAKING INSTRUCTION BEYOND THE GIS LABORATORY

Many universities have added GIS courses with laboratory components during the past decade. Montana State University and the University of Canterbury (New Zealand) have: (1) acquired 'state-of-the-art' GIS software; (2) implemented new courses in GIS and remote sensing; (3) developed collaborative links with resource management agencies to provide additional training opportunities for students; and (4) offered a variety of continuing education options for off-campus professionals. Traditional measures such as class enrollments, evaluations and job placements indicate the success of these programs. However, as in many institutions these programs do not, of themselves, integrate GIS within a mainstream disciplinary context. Both universities are now approaching the development of the first of many initiatives that will be required to achieve this goal. This paper discusses some of the key challenges to be addressed and limitations to be overcome in implementing GIS and other automated geoprocessing tools throughout university curricula. The two strategic aims of mainstreaming are significant: to enhance learning and to ensure that GIS is not wastefully marginalized as many quantitative techniques have been previously. The latter is particularly critical in terms of our ability to contribute scientists and engineers to a future workplace in which the querying, display and analysis of digital spatial data is common.

Many universities have added GIS courses with laboratory components during the past decade (Morgan and Bennett 1990; Morgan and Fleury 1992). The high cost of GIS software and the advent of the NCGIA Core Curriculum (Goodchild and Kemp 1990), which has been an invaluable and influential document in the diffusion of GIS courses for undergraduates, have helped to position GIS as a separate, predominantly technical area (Aangeenbrug 1992; Kemp et al. 1992; Forer 1993a; Morgan and Fleury 1993).

This paper reviews the current situation at two universities and examines the rationale and options for the wider integration of GIS-related learning as a complement to, rather than replacement for, specific GIS courses. The focus of the discussion is the use of GIS tools to support learning in a range of contexts. While still relatively poorly developed, the inclusion of GIS in mainstream teaching will be favored for growth during the next decade by declining costs, an increasing pool of educators with GIS proficiency, and the emergence of a growing number of 'encapsulated' GIS tools designed for non-specialist use.

LABORATORY-BASED GIS INSTRUCTION

The history of and context for the implementation of GIS courses at Montana State University and the University of Canterbury are very different and yet these two case studies illustrate many of the strengths and weaknesses that are likely to accompany traditional laboratory-based GIS instruction.

Montana State University is a land-grant institution with approximately 550 faculty and 10,500 students. The beginnings of GIS on this campus can be traced to an equipment grant funded by the National Science Foundation's Instrumentation and Laboratory Improvement Program in 1988. The scope and size of the GIS initiative was expanded later that same year with a large grant from the M.J. Murdock Charitable Trust and university matching funds. The paucity of equipment and interest prior to this time, the advent of local area networks (LANs) and high-performance workstations and personal computers (Pcs), the increased number and visibility of commercial GIS software, and the growth in interest in GIS technology and applications among faculty and students in multiple departments afforded the institution an unusual clarity of purpose and the opportunity to build a single campus-wide GIS facility (Wilson 1992).

A Geographic Information and Analysis Center (GIAC) was established in 1989 and is responsible for the acquisition and operation of GIS and remote sensing facilities on campus. The Center crosses college and department boundaries drawing its expertise and clientele from the areas of agricultural engineering, agronomy, architecture, biology, civil engineering, computer science, entomology, geography, geology, political science, soil science, and statistics. The facilities include: (a) ARC/INFO and ERDAS running on Digital workstations and ArcCAD, ArcView, IDRISI, and PC ARC/INFO running on IBM-compatible 486 and 386 Pcs; (b) several Calcomp and Summagraphics digitizers and a Houston Instruments scanner for data input; and (c) an assortment of disk and tape devices for storage and Calcomp, Digital, Hewlett-Packard and Raster Graphics plotters and printers and a Polaroid film recorder for output. These facilities are spread among nine different sites and the workstations and several of the Pcs and peripherals are connected via a LAN. The GIAC is currently staffed by a director and three GIS specialists. These staff and facilities support GIS instruction, research, and outreach.

Instruction covers both GIS education and training (Wilson 1992). There are two semester-length GIS courses which more or less follow the NCGIA Core Curriculum (Goodchild and Kemp 1990). The first GIS course includes a laboratory component with IDRISI and PC ARC/INFO exercises. The IDRISI software is also used for laboratories in two remote sensing classes. The more advanced remote sensing class and the advanced GIS course require further development and will in the future make use of the full range of GIS and remote sensing software supported by the GIAC. These classes address education as defined by Kemp et al. (1992) in that they cover the principles and conceptual issues which surround GIS and remote sensing. Other classes and opportunities provide GIS training in that students can also take the "Understanding GIS: The ARC/INFO Method" self-guided tour (Hicken et al. 1991) for individual problems credit, and selected graduate students and occasionally undergraduates are employed in the GIAC working on collaborative projects with federal and state resource management agencies. Both these initiatives introduce the technical skills necessary to operate ARC/INFO and occasionally the ERDAS and IDRISI software packages.

The research applications are built around approximately two dozen faculty and graduate student research projects with substantial GIS components. Many of these projects are multi-disciplinary and tied to environmental assessments and hydrologic modeling applications. The number and variety (in terms of disciplinary background) of graduate students with GIS and remote sensing thesis projects has increased dramatically in the past two years. The GIS outreach mixes GIS education and training and consists of ESRI's 3-day PC ARC/INFO course and a variety of shorter workshops on special topics (GIS and terrain analysis, farm mapping, groundwater contamination, etc.). The 3-day ArcCAD and 5-day PC ARC/INFO courses will be offered for the first time this summer.

The University of Canterbury is located in Christchurch on the South Island and is the second largest in New Zealand. It is similar to Montana State University in terms of number of faculty (650) and student enrollment (12,000). However, GIS is treated very differently in that the University has left GIS resource acquisition to individual departments. The Department of Geography was the first to enter the area in 1987 with a single graduate course. It was able to extend its scope significantly thanks to an individual research grant from the University Grants Committee coinciding with building expansion and equipment acquisition opportunities. At this time, 1989, the department acquired copies of workstation ARC/INFO and ERDAS as graduate student facilities. The Sun Sparcstation platforms have been consistently upgraded and are now complemented by a Roland 8-color pen plotter, Numonics digitizer, several inkjet printers, a 24-bit scanner, and Magellan Navstar 5000 GPS stations.

The Departments of Computer Science, stressing spatial database design issues, and Civil Engineering, with an accent on survey and data capture, now offer complementary courses in GIS with a degree of informal integration between geography and these other departments. The Departments of Management Studies, Geology, and Forestry also operate individual PC-based GIS systems for research and individual study purposes. There is little standardization of software at the present time, and Geography remains the only ARC/INFO site. Within Geography, the preference has been to avoid PC ARC/INFO and concentrate on delivery via Sun Sparcstations, either directly from Sun consoles or using X terminal emulation on 15 Acorn A5000 RISC workstations in the department's teaching laboratory. Geography also utilizes Alexander from ITC for teaching and IDRISI for individual student projects, and the Atlas-Pro, Tech-Base, GRASS, and Intergraph MGE systems are available in other departments.

The initial GIS graduate class in Geography is now complemented by a new graduate course in remote sensing and a third year 'module' that is effectively only available to geography majors. A second year GIS course that would cater to a larger number and variety of students also has been proposed. As in most institutions the NCGIA Core Curriculum has been of great value as a yardstick for course design, although within the constraints of a limited course structure a somewhat different course synthesis has had to be achieved. Contributions are also made to courses and graduate student supervision in Computer Science and Civil Engineering, and a program of extramural (i.e., outreach) courses is underway. Liaison with government departments and the private sector occur partly through this medium, but more specifically through collaborative graduate student thesis projects and through the enrollment of their staff in the regular GIS and remote sensing courses. The deliberate focus of GIS is on problem-solving in environmental science, and the graduate GIS course attracts a growing number of environmental scientists.

The dilemma facing the Department of Geography at Canterbury is how specific GIS courses can best be related to the remainder of the undergraduate geography curriculum. Canterbury offers a range of courses, with increasing choice at the advanced level. Prerequisites define a number of semi-compulsory 'core' courses, which are viewed as providing the common foundation for students. In the second year these are Human and Physical Geography and a project-based course. The crux of the problem is that it is acknowledged that the opportunity should be available to take a specifically GIS component, but there is no consensus that this should be a compulsory course. However, there is a feeling that some exposure to GIS should be mandatory. The solution, in various guises, is to mainstream aspects of GIS into the core, but the vehicles for this need careful design.

These two case studies provide an interesting and reasonably common starting place for those interested in the inclusion of GIS in mainstream teaching. The two institutions have similar equipment to many others (Palladino and Kemp 1991) and their GIS classes more or less match the typical academic program laid out by Morgan and Fleury (1993). This type of learning environment (if set up properly) offers the advantages of quality and deeper comprehension. Traditional measures such as class enrollments, student evaluations, and job placements suggest both institutions are doing a good job, and the classes at Montana State University, in particular, are noteworthy because they draw their clientele from 6-12 degree programs (Wilson 1992). However, these classes favor the small numbers of students who aspire to be GIS specialists and largely ignore the large numbers of students who do not need to address GIS directly through courses but need some knowledge of the tools in use.

Several solutions for serving a larger number and variety of student needs have been proposed. A few universities have set up GIS degree programs, although there is an ongoing debate about whether or not a university education in GIS itself is more desirable than that offered by the traditional disciplines of geography, computer science, engineering, etc. (e.g. Gittings et al. 1992). Others are worried about the peripheralization of GIS in geography and other disciplines (e.g. Unwin 1991) and the tendency for GIS to replace other "geographic skills" classes in an already crowded curriculum (e.g. Goodchild 1985). Goodchild (1985) at one time proposed an introductory course in GIS, with an emphasis on the core subjects 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 as a solution to some of these problems. Kemp et al. (1992) have since argued that this structure would emphasize the unique character of geographic information that underlies all geographic data handling technologies, but they fail to address who would teach this class and the number and type of clientele that would be served. Many institutions lack the resources to teach this type of class to large numbers of students and many faculty in geography as well as other disciplines would take exception to the dominant position which is assigned to GIS with this type of curriculum model.

The remainder of the paper explores the possibilities for integrating GIS in a broader learning context, based on the premise that some level of technical comprehension can be imparted within a non-technical course framework.

MAINSTREAM NICHES FOR GIS

The use of an integrated GIS approach is, by definition, applicable to many situations. Common options that exist in most mainstream geography programs occur within courses which are principally either: (a) systematic; (b) regional; or (c) focussed on integrated project work. It is asserted that all such courses may utilize GIS tools for learning support: (a) within traditional laboratories, based on a monitored task; (b) as part of Self-Paced (informally timetabled) Units (SPUs); or (c) as a means of delivering access to necessary data, simple techniques and support material (infrastructure). At present the laboratory slot is still the most common environment for computer aided learning, and the simplest option for GIS involvement. Self-paced units have considerable potential, especially in constrained training exercises, but require greater development time, as does the development of an enabling infrastructure.

Each identified kind of course has potentially different requirements. In most systematic courses the focus is on discrete laboratory exercises targeted at particular themes, for instance examining the pattern of urban housing prices or change of agricultural land use between one satellite image and another. By contrast regional courses may require the delivery of comprehensive background material and data. This can certainly be the dominant need within project-oriented courses. Forer (1993a) has argued that applying GIS in learning support in any of these roles, to an audience that is intelligent but not necessarily mentally equipped or well oriented for GIS, requires careful design which stresses four characteristics: usability, user protection, expandability and integration:

> ***Usability*** is the most visible requirement, and one which has been widely viewed as absent from much GIS software (e.g. Raper and Green 1992). The advent of a range of powerful graphic user interfaces (GUIs), user-oriented GIS designs and, on some software, of GUI development tools, has helped reduce the problem of introducing the technically inexperienced users to embedded GIS tools, especially in the limited context of a constrained laboratory exercise. GUIs remain poorly developed in some areas, and often not consistent across and within platforms. Nonetheless, they clearly simplify the specification of tasks by the user and introduce an effective and gentle learning ramp. For GIS we now acknowledge the unique problems of GIS GUIs (Lanter and Essinger 1991) and Initiative 13 of the NCGIA illustrates ongoing activity in this area. For many stable and less complex applications we can expect to be able to present an increasingly encouraging face to the user.

User protection is the design of systems to insulate the user from data imperfection or user ignorance. In learning support this is related to offering resources at a level the individual can cope with. Generically, user protection aims to reduce the chances of malpractice, or if necessary to recognize malpractice and discourage or prevent it. User protection has been highlighted by a number of authors as a necessary alternative or complement to assuming educated users (e.g. Beard 1989), and is clearly significant in a learning situation. Once again, implementation is simpler in a laboratory exercise context where purpose is focussed and the data sets used can be stable and vetted.

Extensibility is a requirement to allow users a graded learning curve, which encourages greater, wider and more informed use of any technique and/or data where motivation exists. This principle is important in allowing extension of the more able, and also subsequently in encouraging the secondary dissemination of their experiences through peer communication. Extensibility is perhaps most significant in the area of SPUs and project infrastructure (i.e. in areas where student goals and timetable are less constrained and thus where a desire to probe and develop can be most easily fulfilled).

Desktop integration is the final principle, which says that the user should be encouraged to see any specific tool for learning about digital spatial data as part of a larger suite of tools. Data can be moved between tools and many tasks can be assisted by the simultaneous application of a number of tools. In a GIS context this is the recognition of the mutability of spatial data, and the need to access a range of tools, whether for analysis, for presentation work or, very importantly, for tutorial assistance. Environments which make these links difficult to achieve hinder progress significantly, while advanced and intermediate multi-tasking desktop environments facilitate such developments.

Each of these four characteristics is important to laboratory, SPU and infrastructure applications utilizing GIS tools. Scheduled laboratories represent the least demanding context, both because the exercises are quite often artificially constrained and because of the availability of immediate human counselling. Computing environments which implement extensibility and integration are less important here, and the existing body of GIS laboratory material includes many examples of specific applications or contexts which could be reworked to focus on theme rather than technique (e.g. Dodson 1991a, 1991b; Dodson et al. 1991). Several software products and digital databases released in the early 1990s offer scope for development of issues in further areas, especially political and socio-economic patterns at a range of costs. The ArcView product from ESRI, Inc. probably represents the most widely applicable tool for building simple laboratory applications available at present (ESRI 1992a). The blocks to faster development of GIS-enabled laboratories in the mainstream are essentially organizational (skills and technical support), resources, and the time required to customize material to local systems and needs.

SPUs are more complex. The emergence of multimedia and hypermedia systems enhances some laboratory units, but are far more vital for enabling SPU development. GISTutor (Raper and Green 1989, 1992) is perhaps the best example of this type of system. The GISTutor runs in Hypercard and provides students with substantial freedom in the selection, sequencing and depth of the topics chosen for review, within constraints set by the designer (Kemp et al. 1992). Merchant (1993) offers a favorable assessment of this system and the EPPL-7 demonstration package developed by David Wherry at Washington State University. The second package is constructed around a series of hypothetical case studies and a menu allows users to select and run short modules on basic GIS concepts. It runs as a stand-alone package and does not require users to have the EPPL-7 software, unlike the GIS Concepts Kit (ESRI 1991) which requires the PC ARC/INFO software. We have tried the GIS Concepts Kit at Montana State University, but found our students frustrated and disappointed that many of the ARC/INFO commands were automated in SMLs and thereby hidden from the user. The nature of multimedia and other kinds of authoring tools makes them by themselves only partially adequate for implementing even simple GIS display or query functions for general use (Forer 1993a). Combining such multimedia systems with GIS tools offers exciting possibilities, as intimated by Foote and Holze (1993 pers. comm.). They aim to develop a suite of GIS-enabled learning units that tackle a number of classic themes (e.g. Engel's London in 1862, endangered species, Roman Britain, future water assessments) for a broad range of liberal arts students. The common links across themes are the use of GIS as core technology and the acceptance of multimedia data types.

Infrastructure systems are the most unstructured category, which attempt to make a wide variety and range of resources available for project work mediated through, or linked to, a variety of GIS sources and tools. Their essence is browsing and data exploration. The best known and most ambitious system with these attributes is probably the Domesday system (Oppenshaw et al. 1986) but a number of more limited alternatives have since appeared (e.g., PC GLOBE and similar database products). These systems do not really grasp the opportunities of current technology and for that reason may not be suited to upper-division or project-driven classes. None of these systems has found widespread use.

The next sections describe two attempts to extend function in this area. The first discusses an effort underway at Montana State University to use the ArcView/ArcWorld products in world regional geography and environmental geography class settings. The second reviews an integrative experiment for a project-based class under development at the University of Canterbury.

GIS AS A REGIONAL GEOGRAPHY DATA SOURCE

Our first example of the inclusion of GIS in mainstream teaching is directed at the freshman World Regional Geography class at Montana State University. This class is taught once or twice each semester to approximately 800 students per year. The class is part of a university-wide core curriculum and as such, it was redesigned five years ago to emphasize critical thinking and writing. These skills are developed with the help of workbook exercises (Wyckoff et al. 1989, 1993) and 2 or 3 graduate teaching assistants per course section. The first edition of the workbook was designed to supplement several world regional geography textbooks. It included regional summaries, place name lists and blank maps in addition to a suite of eight exercises which utilized some combination of maps, library reference materials and surveys to carry out regional and country-scale assessments. Two or three exercises are used each semester and they typically count 20-35% towards the students' final grades.

The success of these innovations has increased class enrollments and overwhelmed a library with single copies of the encyclopedias, yearbooks, and other key reference materials used in several exercises. The release of ArcView for Windows (ESRI 1992a) and the accompanying ArcWorld 1:25M database (ESRI 1992b) offers new opportunities for innovation. The workbook has been rewritten to include an appendix introducing the ArcView software and ArcWorld 1:25M database. Selected parts of the ArcView and ArcWorld user's guides have been rewritten to provide students with three guided tours: the first illustrates ArcView commands and shows how they can be used to query the Browse Map for global assessments; the second tour shows how the ArcWorld 1:25M database can be used to prepare regional maps and data summaries; and the third tour shows how the database can be used to print country maps and data tables. Students are invited in the first chapter of the second edition to substitute the ArcWorld Browse Map for the regional data summaries provided with the first edition of the workbook. The instructions and guidelines for several of the exercises also have been rewritten so that students can (if they want to) use the ArcView software tools to query and display the maps and data in the ArcWorld 1:25M database. These exercises ask students to: (a) compare and contrast investment opportunities in one developed and one less-developed region assigned by the instructor; (b) research a country assigned by the instructor and conduct a survey to find out how much other students know about it; (c) provide a quality of life assessment for countries in a less-developed region assigned by the instructor; and (d) provide maps and a paper comparing two countries assigned by the instructor to help their parents in choosing one of these countries as the destination for their next vacation.

Our approach is ambitious in that the World Regional Geography class is currently taught by two non-GIS faculty and because of our plan to install the necessary software and database on Pcs in the reference section of the library. Three 486 Pcs and some type of printer will be purchased and dedicated to this class. There remain three potentially serious and unanswered questions: Will 3 Pcs be able to serve as many as 400 students per semester? How many students have the necessary skills and motivation to learn these new tools? Will students be able to use these products to their advantage? We hope to alleviate the first potential problem by: (a) making the use of the ArcView and ArcWorld 1:25M products optional, and (b) staggering the due dates for the ArcView exercises so we can monitor use levels and thereby position ourselves to make resource changes if necessary. The provision of three Pcs is in some respects an improvement over the current situation in that as many as 400 students are directed to one or two key reference materials.

The last two potential problems stem from the suspicion that there are still many university students out there with poor skills in, or a phobia for, computers and digital information (and by false equation on their part) computer science and mathematics. Those involved with the workbook and class have different views. The two World Regional Geography instructors (Ashley and Wyckoff) think that only 10-20 students per class will have the background and motivation to successfully supplement their learning with these tools. The third workbook author (Wilson) hopes that the latest edition by providing an integrated approach, in which an aspect of GIS use is set in a secure setting, will offer a larger number of students help in solving their potentially serious dysfunction, and may alert others to some new and exciting opportunities. We clearly need some data (experience) to be able to evaluate the relative merits of these different views and the software tools which are to be implemented.

GIS AS A PROJECT SUPPORT TOOL

The second example from the University of Canterbury also tackles course infrastructure but differs from the first example in terms of level of innovation (greater) and size of intended audience (smaller). Havelock is a trial unit developed for support of a second year geography class with an individual project undertaken within the boundary of a class study area. This class runs for the entire academic year and has a maximum of 50 students. The needs of the students are very typical of a range of broad users of spatial data and focus on access to data: (a) for browsing; (b) for defining or executing projects; and (c) for inclusion in final reports. The class already emphasizes the integrated digital workbench, encourages the use of digital sources and tools and requires a final report compiled via desktop publishing. The specific aim is to simulate the likely working environment of graduates. Havelock attempts to take this one step further by providing a rich resource of first recourse to students, which will implicitly encourage the use of GIS data and simple techniques (Forer 1993b). It does this by concentrating a wide range of data sources useful to their study (e.g. a complete regional bibliography, scanned aerial photography, remotely sensed images and vector maps) into a single source. This source, which has a multimedia application as its kernel, is easy to access, has the ability to export its contents into written project work, and offers linkages to a growing number of manipulative tools.

Havelock is built around four significant and integrated components: (a) A GUI environment offering a largely consistent advanced interface using both Sun's Open Windows and Acorn Computer's RISC-OS -- both offer a similar style, and can be integrated under X across a LAN; (b) a LAN, utilizing NFS and TCP/IP protocols, which is campus wide; (c) a hypermedia authoring system (in this case Genesis II (Oak Solutions 1991)) which acts as a kernel for coordinating resources and is based on local workstations, predominantly Acorn A5000s; and (d) a suite of tools, both micro- and network-based, which gives access to different forms and views of data. These tools include image processing packages, such as Alexander from ITC, draughting/cartographic packages (Vector), simple data bases, ArcView under X and a customized bibliographic package. The system architecture allows for concurrent use of browsers, tools and support units as well as simple transfers of resources between these areas.

Havelock uses multimedia authoring tools to form an 'open' kernel. These tools are still predominantly restricted to stand-alone micros, but are capable of tutorial support and simple graphic manipulation. They do not offer either the range or speed of graphic and database programming to allow development of a complete 'closed' kernel and toolbox for any significant GIS functionality, even if this were desirable. This is an obstacle to creating an integrated and distributable product. However, an open and mixed environment does encourage the development of an easily customized core which can be modified to relate to an evolving variety of tools. RISC-OS and Sun's Open Windows were initially favored over rival systems because of their superior ability to support such an environment. The kernel in Havelock currently performs three functions: (a) allowing elementary browsing of a variety of data types; (b) enabling links to analytical and advanced browsing tools; and (c) providing student support. In the current implementation all of the support and tutorial material is handled by the kernel, and is available simultaneously with any other items. Launching any item usually offers students the choice of starting simultaneous help functions.

Most of the simple browsing is also undertaken through the authoring software. Text, images (RS and landscape), vector maps and symbol libraries, sound and animations (computer generated and video) are supported. An important characteristic of the authoring software, apart from low cost, is the ability to drop material from the kernel in appropriate formats into the user's report-writing environment. Local bibliographic packages, combined with hypertext features in the software and some simple map and time indexing implementations, enhance this aspect of browsing. Since the data is largely read-only it becomes possible to implement some rudimentary user protection through controls on data quality and compatibility, and to augment these by on-line lineage documentation and advice on suitable uses.

More sophisticated browsing and analytical functions are handled by local and LAN-based external tools. These tools include, at the sophisticated end, ARC/INFO and ArcView under X, but also locally based image processors and mapping packages and the productivity tools which between them form the desktop working environment. Routes exist for undertaking most of the transfers between tools that might be required within the scope of this particular course: they are largely automatic within Open Windows and RISC-OS, and can be simply automated for cross-platform transfer.

Havelock is a prototype attempt to simulate a data rich environment for informal learning that features a number of GIS capabilities. At present its development focuses on browsing resources of various kinds, largely within the kernel or ArcView. Its evolution will undoubtedly seek to extend its scope to a wider tool range and make its support features for user-driven learning more effective. It will also attempt to become more portable, in terms of delivering its services to students on a spatially and temporally flexible basis. This will probably be accomplished via an increased use of X or a similar client/server arrangement.

CONCLUSION

This paper has reviewed the current situation at two universities and examined the rationale and options for the wider integration of GIS-related learning as a complement to, rather than replacement for, specific GIS courses. These GIS courses serve the aspiring GIS specialist well and largely ignore the large numbers of students who do not need to address GIS directly through courses but need some knowledge of the tools in use.

The promotion of 'mainstreamed' GIS will help several different groups: (a) for those already enabled by a GIS course such developments permit reinforcement of their skills through everyday use in other areas; (b) for those less skilled in GIS it offers an opportunity to broaden the potential GIS user base; and (c) it offers an opportunity to alert students to the modern wayfinding and consumer information systems in which the querying, display, and analysis of digital spatial data is commonplace.

The kind of approach discussed here advocates conscious design, and seems to have some validity as digital spatial data moves from its current clientele to a wider audience. The arguments, although limited to the geography programs at two institutions in this paper, would seem to apply to many other academic programs in geography and the other disciplines with spatial interests (biology, civil engineering, geology, range science, soils, etc.). The kinds of GIS tools discussed in this paper may be critical to ensuring that the elite who are highly skilled in the manipulation of geographic information are complemented, apace, by a broader base of informed users and consumers.

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