GIS Education through Certificate Programs

by Thomas A. Wikle

***Abstract**: This paper presents an overview of GIS certificate programs available through colleges and universities in the United States and Canada. It is argued that by presenting a structured sequence of coursework, GIS certificate programs have begun to address the varied educational goals of both traditional students and non-degree professionals. A survey of certificate programs listed on the World Wide Web reveals considerable variation in the structure, duration, sponsorship, and intended student population associated with GIS certificates. Given demands for increasingly specialized GIS training, it is suggested that new certificate programs should be defined according to application area (horizontal) and position type (vertical) dimensions. Issues surrounding the design and implementation of new certificate programs are also reviewed.*

Introduction

Supported by advances in computing power and the increasing availability of spatial data in digital form, geographic information system (GIS) technology continues to grow in its use and societal importance. Unfortunately, many higher education institutions and other organizations that provide GIS training and education have found it difficult to meet the burgeoning demand for GIS instruction. Complicating the situation is the increasingly diverse type of student pursuing these opportunities. Along with traditional college students preparing for entry-level jobs are larger numbers of non-degree professionals seeking basic or advanced GIS education and training. As suggested by Huxhold (1991), a portion of these returning students consider GIS experience and education to be a more important factor for obtaining a GIS position than the type of degree they hold.

Presently, GIS education and training needs are being addressed by activities ranging from short-term training sessions such as mini-courses, seminars, and workshops, to programs of longer duration including certificates and academic degrees (Wikle 1998). However, despite demands for a broader range of GIS coursework, most colleges and universities focus on a "one size fits all" approach to teaching GIS that channels all students through a single course or course sequence. What is missing at many higher education institutions is a method for connecting courses within logical sequences designed to meet specific and sometimes diverse educational objectives. The academic certificate has emerged as one method for providing this structure.

A GIS certificate can be defined as a package of GIS and related courses that provides recognition for the completion of coursework outside of or in addition to a regular degree program. GIS certificates are presently offered at over 40 colleges and universities, mostly within the United States, Canada, Great Britain, and Australia. However, despite similarities in their names such as "Certificate in GIS" or "GIS Operator's Certificate," GIS certificate programs are extremely diverse in their structure, duration, sponsorship, and intended student population. While some offer considerable depth in their treatment of theoretical issues, applications, and allied disciplines, many others provide only applied GIS training. Given the recent expansion of GIS certificate programs, it is important for those planning instructional programs to appreciate the benefits and limitations of certificate programs for educating future GIS professionals. The purpose of this paper is to summarize the attributes of GIS certificate programs offered by U.S. and Canadian colleges and universities and to present suggestions concerning curriculum planning that may assist in designing programs that better address the competencies needed by future GIS professionals.

GIS Education: A Look Back

In contrast to other computer technologies that emerged during the 1960s and 1970s, GIS was relatively unknown outside a few of government agencies, private companies, and larger universities. As noted by Kemp (1993), in these early years of GIS education, students and professors learned together as they explored the application of computer science, computational geometry and spatial statistics to complex geographic problems. Increased in-

Thomas Wikle *holds a Ph.D. in geography from Southern Illinois University and is currently Professor and Head of the Department of Geography at Oklahoma State University. His recent research has focused on dialect geography and the spatial patterns of volunteer organizations.*

Table 1. Certificate Programs Surveyed in 1998

College or University	Certificate Offered
Algonquin College	GIS Certificate
BTR Labs	Certificate in GIS and GPS
California State Univ. at San Bernardino	Certificate in GIS Applications
Chippewa Valley Technical College	GIS Technician Certificate
Cleveland State Univ.	Certificate in GIS
California State Univ. at Long Beach	GIS Certificate
DePaul Univ.	Certificate in Cartography and GIS
Ferris State Univ.	Certificate in GIS
Holyoke Community College	GIS Certificate
Mohawk College	GIS Programmers Certificate
Montgomery College	Cartography and GIS Certificate
Northern Alberta Institute of Technology	GIS Certificate for Supervisors/Managers
Northern Territory University	Graduate Certificate in GIS
Northern Virginia Community College	GIS Certificate
Nova Scotia Community College	GIS Certificate
Oklahoma St. Univ.	Certificate in GIS
Penn State Univ.	World Campus Certificate in GIS
Rowan College	Certificate in Cartography and GIS
Rutgers Univ.	Certificate in Geomatics
Ryerson Polytechnic College	Certificate in Digital Geography and GIS
San Diego State Univ.	Certificate in GIS
San Francisco State Univ.	GIS Certificate
Simon Fraser Univ.	Certificate in GIS
St. Mary's Univ. of Minn	GIS Certificate
State Univ. of New York	Certificate of Graduate Studies in GIS
Univ. of California at Riverside	GIS Certificate
Univ. of Albany	Certificate in GIS and Spatial Analysis
Univ. of Connecticut	Certificate in GIS
Univ. of Denver	Certificate of Adv. Study in GIS
Univ. of Georgia	Graduate Certificate in GIS
Univ. of Georgia	Certificate in GIS
Univ. of New Haven	Certificate in GIS
Univ. of Northern Alabama	Certificate in GIS
Univ. of Winnipeg	Certificate Program in Remote Sensing and GIS
Univ. of Wisconsin at Milwaukee	Certificate in Urban GIS
Univ. of Washington	Certificate in GIS
Univ. of Southern California	Geographic Information Science Certificate
Univ. of Texas at Dallas	GIS Certificate

terest in the use of GIS technology and greater demand for GIS education during the 1980s raised awareness for the need to make GIS educational opportunities available to larger numbers of persons. An outgrowth of this need, the NCGIA Core Curriculum was developed during the late 1980s to provide a common set of instructional materials to faculty teaching GIS courses (Goodchild and Kemp 1990).

During the 1990s, improvements in microcomputers and the availability of inexpensive and user-friendly GIS software contributed to the growing number of people who could utilize GIS. However, the relative shortage in GIS educational opportunities led to a tendency for some GIS users to equate software expertise with GIS knowledge (Marble 1998).

In an effort to coordinate the instruction of GIS and related courses, the first GIS certificate programs appeared in the early 1990s. As noted by Long (1992), American universities have offered certificate programs since the 1940s, but it was not until the 1970s that certificates became popular as a result of technological innovations and changes within the workforce. The principal objective of an academic certificate is to offer formal recognition through completion of a structured set of courses linked within a concentrated field of study (Robinson 1991a; Hoover 1996). Certificates differ from degree programs mostly in terms of their focus and duration. In contrast to degree programs that include general education courses, certificates are narrowly focused and require less time to complete. For working students, the choice between a degree program or certificate often reflects attempts to balance professional and personal obligations.

Academic certificates should not be confused with certification or accreditation processes. In contrast to a certificate earned through the completion of coursework, certification involves

demonstration of competency and mastery of a body of knowledge through an examination or peer review (Wikle 1998). Most certification programs are administered by a professional association of practitioners in the field. As noted by Obermeyer (1993), accreditation is a designation bestowed upon an academic program to recognize the maintenance of standards in terms of curricula, faculty numbers and qualifications, and facilities.

Academic certificates offer a number of benefits to individuals, employers, and sponsoring academic programs. For example, by demonstrating focused study outside regular degree requirements, a certificate can become valuable to persons seeking employment. Non-degree students interested in addressing gaps in their knowledge can also benefit through full or part-time work towards a certificate. For professionals, the completion of a certificate can lead to greater earning power and career advancement (Robinson 1991b). Certificates may also provide advantages to employers through improved services and products and in some cases, may eliminate the need to establish in-house training programs. Finally, certificate programs can provide benefits to sponsoring institutions. Because certificate curricula often include courses from several disciplines, they can become vehicles for promoting cooperation between academic units. For academic institutions sensitive to enrollment trends, certificates may draw students to campus who may not otherwise be interested in furthering their education.

Certificate Programs in the U.S. and Canada

A survey of U.S. and Canadian GIS certificate program descriptions available on the World Wide Web as of November 1998 reveals significant expansion in the number of certificates now offered at colleges and universities. (Table 1) The survey was carried out using key words and several Web-based search engines. Although this method for collecting information is somewhat unscientific, it does provide a good cross-section of programs together with descriptions of admissions criteria, instructional facilities, and program requirements. A few telephone calls helped to address gaps in web-based information. In addition to identifying the current state of certificate programs offered in the U.S. and Canada, the information was also used for making comparisons with information collected through a similar inventory conducted in 1996.

The survey revealed substantial growth in the number of GIS certificate programs now available in the U.S. and Canada. Between 1996 and 1998 the number of programs listed on the World Wide Web increased 43% (from 19 to 44) with programs now offered in 20 U.S. states and five Canadian provinces (Figure 1). The 1998 survey also identified increasing diversity in the range of academic units offering certificate programs. Presently, about one-third are sponsored by a department of geography, however, an increasing number of non-geography departments

Figure 1. Location of Certificate Programs

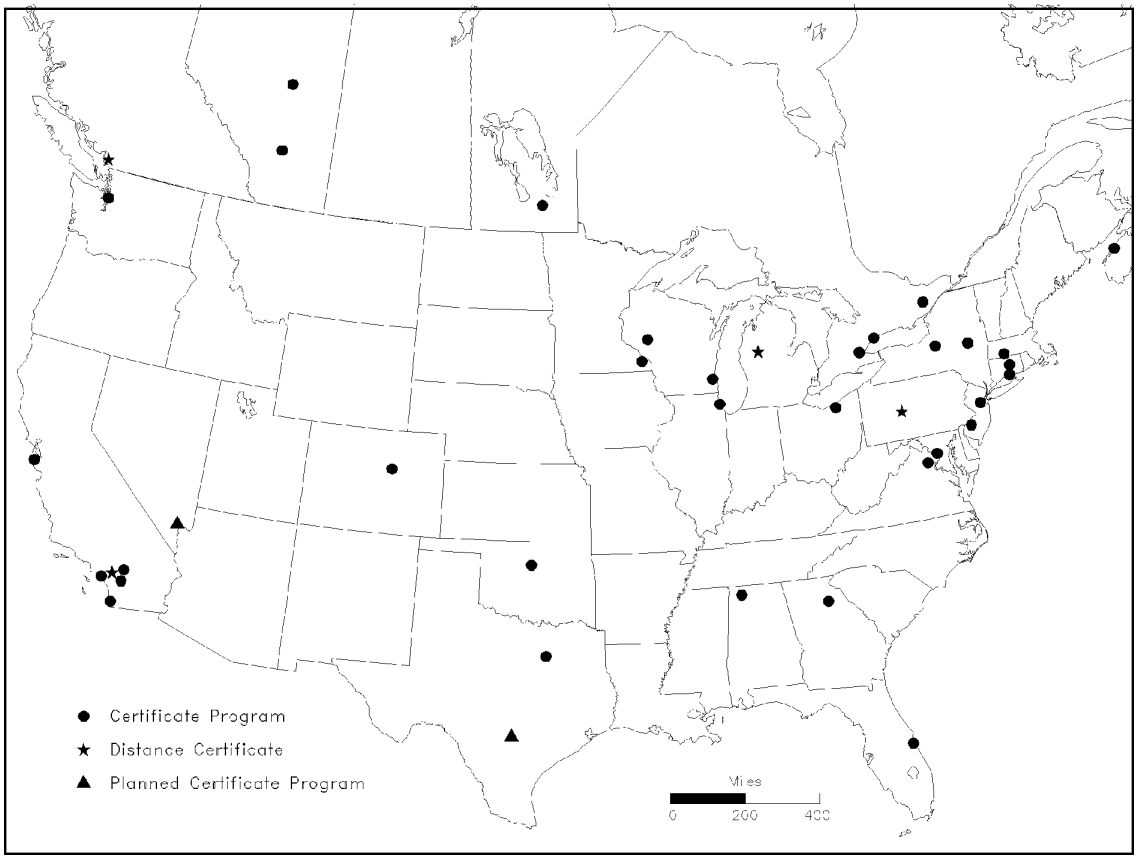
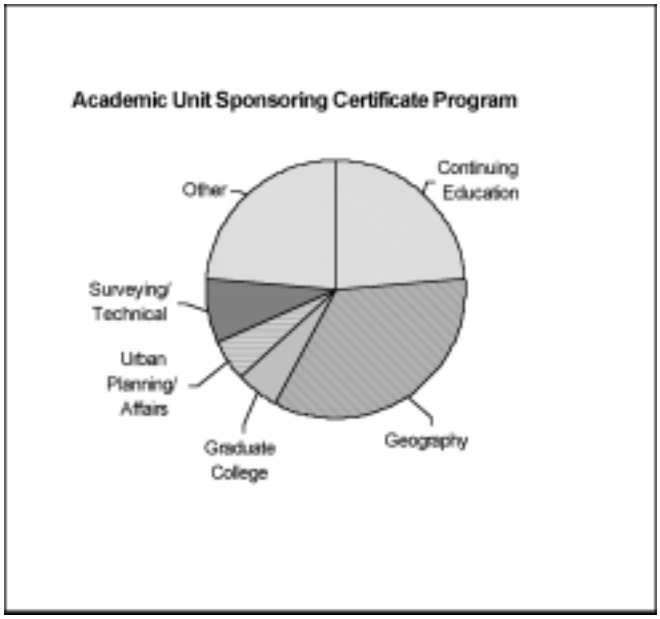


Figure 2. Academic Sponsors of GIS Certificates in 1998



have initiated certificate programs. These include surveying/engineering, urban planning/affairs, continuing education units, interdisciplinary centers, and graduate colleges (Figure 2). Continuing education and extension units currently sponsor about one-fourth of certificate programs offered in the U.S. and Canada. In a few cases, these units offer a certificate through partnerships with regular academic units. Certificates are also offered through interdisciplinary centers such as the *Certificate in Geomatics,* sponsored through the Centers for Remote Sensing and Urban Policy at Rutgers University in New Jersey.

Program Prerequisites

About two-thirds of certificate programs have no course prerequisites. Continuing education units sponsoring certificates were generally less likely to require prerequisite coursework. In contrast, students seeking entry into most programs sponsored by regular academic units are required to demonstrate competency in subject areas or complete prerequisite coursework. For example, the University of Georgia's undergraduate and graduate GIS certificate programs require proficiency in mathematics, elementary computer programming, statistics, database management, and cartography.

Mastery is determined through an advisory committee that assesses each applicant's background preparation. Other certificate programs require a minimum grade point average or score on the Graduate Record Examination.

Coursework

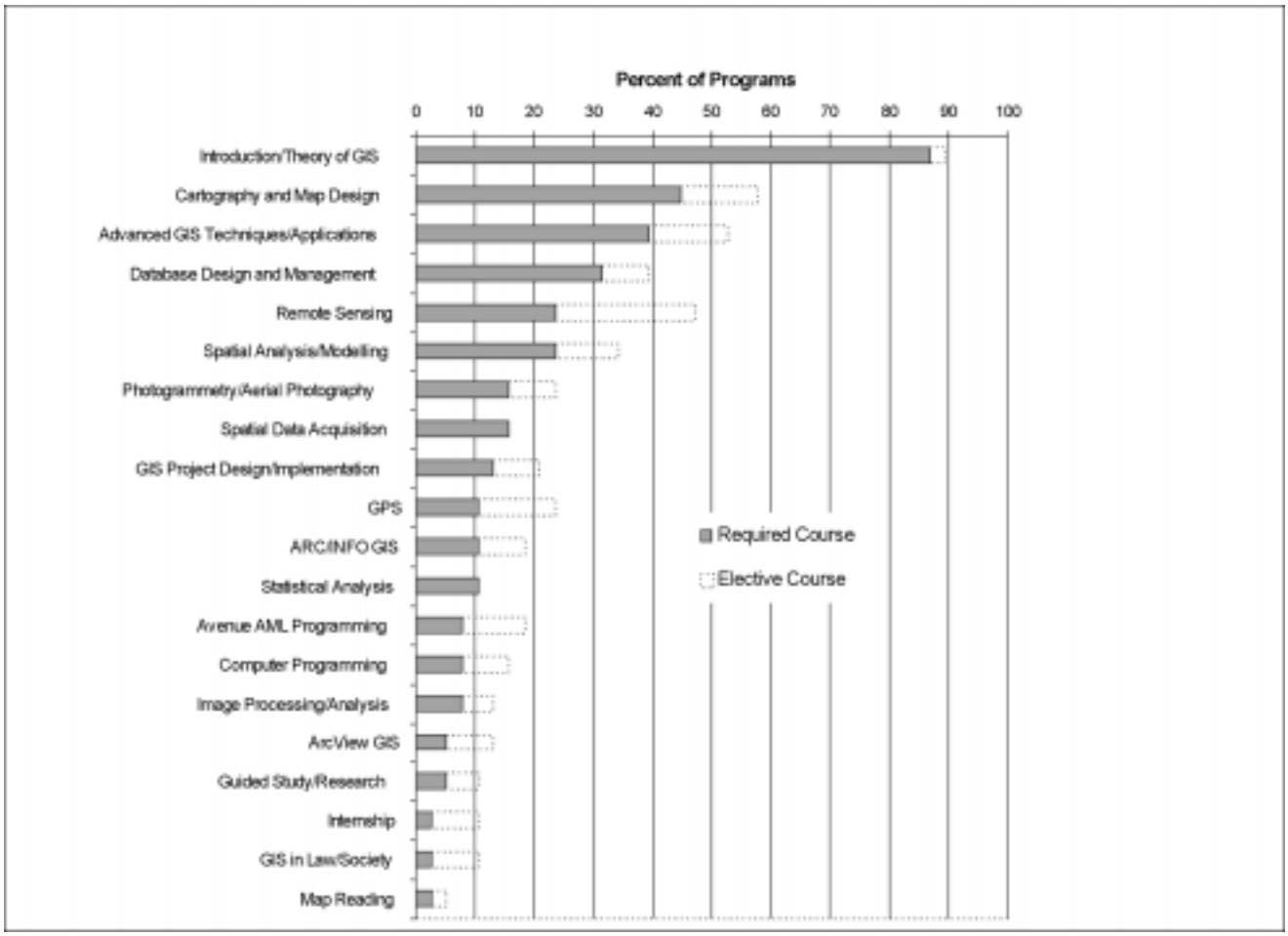
Given the lack of a consensus concerning what constitutes a well-defined certificate program in GIS, it is not surprising that certificate programs vary considerably in terms of course requirements. Such variation suggests that the optimal mix of courses for a certificate program is dependent on program objectives and clientele. The duration of programs surveyed ranged from 110 to 750 class hours with a median of 238. In general, certificates offered through continuing education programs require fewer contact hours than programs offered through academic units such as geography or urban planning. The number of required courses associated with programs ranged from 12 to one with an average of five courses. Elective courses were an option in only about one-half of the programs. A few such as the University Southern California's program offer credit for work experience. Decisions about accepting work experience in lieu of coursework within these programs are typically granted on a case-by-case basis.

Similar variation can be seen in the types of courses students must complete. Over 85% of programs require an introductory course dealing with the theoretical concepts of GIS. In contrast, less than half require a course in digital cartography or map design (Figure 3). While nearly 40% of programs require students to complete an advanced course in GIS methods or applications such as GIS in business or GIS in environmental modeling, only one-third require a course in database design or management. Other courses included within many certificate programs were spatial analysis/modeling, photogrammetry/aerial photography, spatial data acquisition, and GIS project design/implementation. A few programs also included courses dealing with GPS data capture, statistical analysis, or topics tied to specific software packages such as ARC/INFO or ArcView. Computer programming was required in only a small number of certificate programs. For example, Mohawk College of Applied Art and Technology in Hamilton, Ontario requires students to complete courses in C++, Visual Basic, SQL, and Avenue. A few programs require demonstrations of practical knowledge through an internship or project-oriented course. In most cases university faculty make all decisions concerning required and optional courses within the program. However, curriculum planning for some programs, such as the one at San Diego State University, is guided by an advisory committee made up of government and private industry professionals.

Distance Education Certificates

As suggested by Kemp and Frank (1996), there is a large group of possible GIS students who often cannot be accommodated within regular college and university GIS programs. Many of these individuals are employed full-time and cannot leave their positions, even temporarily, to seek education and training opportunities. Distance courses and certificate programs are a relatively new option for these professionals. In most cases, students can complete a distance course or certificate without residence at the sponsoring institution. Admission to most distance programs is open, however a few require demonstration of academic or professional qualifications. Students completing distance programs receive modules through the mail or may download exercises and other course materials. Examples of institutions utilizing

Figure 3. Required Courses for a Certificate in GIS



this delivery method include Penn State's "World Campus" that offers a certificate through the completion of Internet or CD-ROM based assignments. Dialog among students and the instructor is facilitated through email or chat rooms.

Two other North American universities, Simon Fraser in Burnaby, British Columbia and the University of Southern California in Los Angeles offer distance GIS programs in association with the UNIGIS International Consortium of Colleges and Universities. UNIGIS is a consortium of campuses in twelve countries that share materials and software used in postgraduate distance GIS learning programs and coursework. In addition to paying tuition costs, students taking distance courses must have access to a high-end personal computer with modem or network access. The philosophy used in the UNIGIS program at Simon Fraser is that many professionals have solid practical training in GIS but lack a theoretical base of knowledge.

Dimensions of GIS Education

The increasing diversity of GIS applications has begun to generate demands for specialized skills associated with application areas and position levels. As suggested by Petch and Reeve (1996), a single general-purpose GIS course no longer addresses the needs of all GIS professionals working in increasingly diverse fields. This expanding number of GIS application areas, each with unique data and analysis requirements, has created demand for GIS education that falls along a line representing several applications areas and forms a horizontal dimension. Academic units have responded to this demand by offering highly specialized courses, and in some cases certificate programs, that focus on specific needs associated with a narrowly defined applications area. Examples of certificate programs tied to applications areas are the University of Winnipeg's *Certificate in Remote Sensing and GIS* and the University of Wisconsin, Milwaukee's *Certificate in Urban GIS*.

In addition to needs along the horizontal dimension, there is a growing demand for education and training in support of position levels and associated responsibilities, forming a vertical dimension of GIS educational demand (Figure 4). The existence of a hierarchy of GIS position types has become widely recognized (Marble 1979, Parent 1988, Goodchild and Kemp 1990, Heywood and Petch 1991, Toppen 1991, Dymon 1994, Huxhold and Levinsohn 1995, and Capper and Unwin 1996). Although there may be overlap in the activities associated with each, GIS positions can be found within four separate levels: GIS user, GIS technician, GIS analyst, GIS programmer/software designer, and GIS project manager.

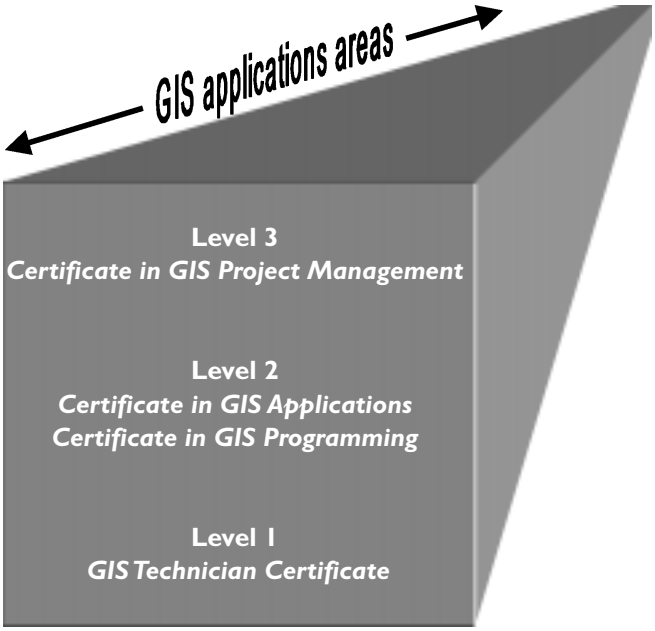
GIS User

Occasional GIS users may not want or need extensive coursework in GIS theory or allied disciplines. For the majority of these individuals, GIS is one of several problem-solving tools employed for specific tasks. However, despite their less frequent use, it is important that this group of GIS users have a basic understanding of GIS theory and applications that includes exposure to topics ranging from data quality to the ethical use of GIS.

GIS Technician

GIS technicians are responsible for routine tasks ranging from digitizing and scanning, to data editing and cartography. Petch and Reeve (1996) estimate that in the coming years, the needs for GIS technicians will exceed that of GIS managers, programmers, and analysts. Despite growth in demand for technicians, educational opportunities for this group have largely been ignored. Although their education and training needs are generally not as extensive as that of analysts, technicians must be familiar with map design, coordinate geometry, and issues tied to spatial error. Ideal venues for offering certificates at the technician level include community colleges and vocational schools.

Figure 4. Horizontal and Vertical Dimensions of GIS Certificates



GIS Analyst

The GIS analyst forms the backbone of GIS problem solving within an organization. A college or university degree in geography or a field tied to the intended application area provides the necessary background. The certificate for an analyst should focus on a solid base of theoretical knowledge in GIS, especially spatial statistics, and specific skills in the use of selected GIS software. In addition, the program should prepare the professional for responsibilities tied to the analysis of diverse types of spatial and nonspatial data. Tasks assigned to analysts include data analysis, map compilation, and report generation. Educational programs designed for this group should also provide exposure to database design principles, metadata, operating systems, and macro languages used to customize tasks within software.

GIS Programmers and Software Designers

In the early years of GIS the difficulty of use and instability of software, coupled with demands for custom applications to address functions not included, necessitated programmers who were familiar with GIS applications and data. Despite recent trends toward GIS software that is easier to use or integrated within other applications, there will continue to be a demand for GIS applications programmers. This need, however, is likely to be greatly exceeded by the need for technicians, analysts, and managers. Although it is difficult to determine exactly how many GIS professionals are primarily programmers, data from a recent Internet survey conducted by the Environmental Systems Research Institute suggests that about 10% of GIS professionals consider themselves to be programmers or applications developers (ESRI 1998). Future GIS programmers will be involved in tasks such as the design of new GIS software and the integration of specific functions within finished applications that can be implemented by end-users (Huxhold and Levinsohn 1995). In addition to gaining computer programming skills and knowledge of operating systems appropriate to the primary GIS application, programmers should complete coursework in data structures, modeling, artificial intelligence, and system design. Given that many GIS programmers and software designers come from disciplines that may not ordinarily consider geographic issues, it is important that educational programs for this group include considerable breadth in topics ranging from coordinate systems to spatial error handling.

GIS Manager

As GIS became more integrated within industry and government, many of the first users or "pioneers" of GIS within their organizations moved into management roles. New responsibilities associated with overseeing a team of GIS professionals have brought challenges to these individuals, some of whom have little formal education in business management. As suggested by Capper and Barry (1996), as one moves up the hierarchy, management rather than technical GIS skills become important. The evolution of a class of GIS team leaders and project managers has created a demand for a new level of GIS education. Unfortunately, the focus of most academic GIS courses is on technical and analytical topics with less attention paid to business or organizational issues. Another problem noted by Petch and Reeve (1996) is that faculty teaching GIS courses often have little direct experience within the business environments in which GIS is used. To be successful in applying GIS within the wider framework of their organizations, managers must be familiar with every potential applica-

tion of GIS. In addition, GIS managers should have exposure to personnel management, project planning, budgeting, cost control, and legal issues affecting the application of GIS within their organization. Solid written and oral communication skills are also important and should be part of a certificate program for GIS project managers.

A Certificate Hierarchy

The 1998 survey found that most colleges and universities offering certificate programs target a wide range of people interested in GIS. As larger numbers of persons within organizations become involved in GIS, generic certificate programs may not adequately address vertical specialization. Depth and diversity of educational requirements associated with various GIS position levels may be best served by designing GIS certificates to meet the unique needs of position types. One model to address the needs of various position types would be to develop a three level certificate hierarchy with technicians in the first level, analysts and programmers/designers within level two, and managers in the third level. Such specialized certificate programs would facilitate the tailoring of academic requirements. For example, coursework in project management and administration would be more important for a program that targets managers while data capture techniques should be emphasized by a certificate designed for technicians. In addition, a vertical classification system could assist employers seeking to evaluate the knowledge or competency expected from a job applicant holding a particular certificate. A few colleges and universities have begun to offer certificate programs that address a specific level. For example, Northern Alberta Institute of Technology offers two distinctly different certificates, the *GIS Certificate for Systems Designers and Builders* (9 courses) and a more limited *GIS Certificate for Supervisors and Managers* (5 courses).

Certificate Design Issues

The creation of a successful certificate program at any institution requires a critical mass of faculty, students, and facilities. High quality faculty are especially important to a program's success given that, next to the success of graduates, the quality of instruction associated with a certificate will have the greatest impact on the reputation of the program (Lopos 1991). In addition to faculty leadership, Walshok (1991) advocates the frequent consultation of practitioners during the process of designing a certificate program. A permanent advisory committee of faculty and GIS professionals is one method for obtaining such input.

Faculty are not likely to support a certificate curriculum that is poorly designed, lacks academic rigor, or cannot be sustained in terms of facilities or technical staff. Unfortunately, little research is available concerning the development or implementation of certificate programs (Crispin 1976, Lopos 1991, Long 1992). In the absence such information, a framework suggested by Hoover (1996) can be adapted for the planning and design of GIS certificate programs (Table 2). Planning issues that must be addressed include the type of program offered (academic or noncredit), the type of student targeted (short-term, full-time, or part-time), the nature of required prerequisites, and the type of faculty who will teach certificate courses (regular or adjunct). Other issues including financial

Table 2. Issues in Establishing GIS Certificate Programs (after Hoover, 1996).

Type of Program: 1. continuing education 2. academic credit terminal (no degree credit) 3. academic credit applicable	Faculty: 1. regular (on campus) 2. adjunct or part-time
Program Management: 1. continuing/extended education unit 2. academic department 3. continuing education/academic partnership	Fees: 1. per course 2. per credit hour 3. for the entire program
Certificate Requirements: 1. required courses 2. elective courses 3. combination of required and elective courses	Course Availability: 1. weekdays 2. weekends 3. evenings
Type of Credit: 1. Continuing Education Unit (CEU) 2. academic credit 3. no credit	Prerequisites: 1. academic coursework 2. knowledge or experience 3. none
Student Type: 1. short-term 2. full-time 3. part-time	Designation of Completion: 1. listed on transcript 2. printed certificate

considerations can be critical to the establishment of certificate programs. On campuses where GIS courses are well established, certificate programs can be implemented using existing campus resources. However, in other cases, support for new courses and equipment must be secured. In addition, the high cost of GIS hardware and software makes long-term maintenance of equipment and software a significant issue. It is therefore important that planners consider the need for laboratories or classrooms equipped to handle the influx of new students as well as maintenance funds for software and hardware so that the facility can keep pace with industry changes and innovations.

Conclusion

The future of GIS in government and industry is clearly dependent on the availability of trained professionals who work at various levels to design, operate and manage the implementation of GIS. As GIS applications become more diverse it will become increasingly important that education opportunities address new demands for education and training. Certificate programs can address this need by linking courses in logical sequences tied to specific objectives. However, regardless of the resources available, successful certificate programs must receive guidance and support from professional and academic GIS organizations.

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