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Scoping Geographic Information Systems for Education: Making Sense of Academic and Practitioner Perspectives

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Abstract

Geographic information systems (GIS) education now takes place in most of the world's colleges and universities, where it involves dozens of disciplines, thousands of instructors, and tens of thousands of students annually. Still, no consensus exists about the scope and content of the field that GIS educators should help students understand. Twenty-five years of inconclusive debate among academic geographers and GIS practitioners are reviewed from a US perspective, culminating in a pivotal lawsuit in US federal court. A broad and inclusive conception called geographic information science and technology (GIS&T) is proposed to help students make sense of the field. GIS&T is an intersection of accredited and non-accredited disciplines, regulated and unregulated professions, and old and new technologies. The interests of organizations and individual practitioners are at once competing and complementary. One common interest is, or should be, the 'body of knowledge' that distinguishes the field from others and defines relationships among its constituent communities of practice. Continuous development of the *GIS&T Body of Knowledge* is recommended as a vehicle for communication and cooperation among the diverse interests that make up the GIS&T field.

Introduction

Many who teach geographic information systems (GIS) in higher education do so within academic disciplines that are not accountable to subject-specific *accreditation* – the formal evaluation of the qualifications and effectiveness of educational institutions and programs. In the United States, geography is the most common academic home for formal courses in GIS (Phoenix 2000). Unlike the faculty members of such related disciplines as planning, landscape architecture, and computer science, academic geographers are not obliged to submit their courses and curricula for external review by an organization like the Planning Accreditation Board, the Landscape Architectural Accreditation Board, or ABET (Accreditation Board for Engineering and Technology). Many GIS educators are called on to develop and teach individual courses, and to plan and implement entire academic programs, in the absence of a disciplinary consensus about the educational objectives that they should help their students achieve, how educational outcomes should be evaluated, or even about the nature of the field in which at least some of their students hope to pursue professional careers. In this article, I aim to 'scope' the GIS enterprise in a way that will prepare educators in geography and other disciplines – particularly those in the United States – to help their students make sense of this vital, dynamic, and contentious field. Here, 'scoping' refers to the process of defining the boundaries and contents of a field of study. I will argue that it is useful to understand the enterprise as an intersection of competing yet complementary interests and values. I also suggest that the various intersecting disciplines and professions share at least one common interest: a formal and comprehensive 'body of knowledge' that specifies the scope and content of the field. And finally, I suggest that the iterative process of defining and redefining this body of knowledge has the potential to foster communication and understanding among the professions and disciplines, to the betterment of the field and the benefit of society. I begin by reviewing some of the debates among academic geographers and professional practitioners that have led to this argument.

Academic Debates

Well before GIS became a household acronym in geography, Jerome Dobson's manifesto (1983a) catalyzed debate about the nature of what would come to be called geographic information science (GIScience), and about its implications for the discipline (Dobson was an early catalyst, but not the only one. Similar debates arose independently in Europe. For a fuller discussion, see Pickles 1995; Schuurman 2000). Defined then as the 'eclectic application' of computerized maps, images, language, and mathematics to 'portray spatial properties, to explain geographic phenomena, and to solve geographic problems,' Dobson (1983a, 136) predicted that 'automated geography' would emerge as a 'major new extension to the discipline' (p. 141). Most provocatively, he claimed that automated geography offered the potential to change geography for the better, by making it more obviously valuable to society, and more attractive to research sponsors in government and industry.

Three months after the manifesto appeared, the *Professional Geographer* published eight commentaries by geographers who were involved in one way or another with the automated geography that Dobson championed. Perhaps because the commentators were insiders, they did not seriously question the assumption that the fulfillment of Dobson's vision, or something like it, would be beneficial to the discipline. Instead, commentators addressed matters of practicality, precedent (i.e. the federal government's abortive attempt to design and implement a Decision Information Display System in the late 1970s and early 1980s), and even preference for names

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other than 'automated geography.' In his reply to a recommendation that the enterprise be called 'computer-assisted geographic systems', Dobson (1983b, 351) stated remarkably that 'what I am talking about is not a system or collection of systems. It is a *discipline* . . . [author's emphasis].' Following his earlier prediction, Dobson now claimed that the new method would become both a discipline and an extension of a discipline. The question of whether automated geography, or (later) GIScience, or (later still) geographic information science and technology (GIS&T), constitute a discipline, or something else, is a key point that I will return to below.

Ten years later, the *Professional Geographer* presented a series of retrospective commentaries that included more substantive critiques by a more diverse collection of authors. One, Eric Sheppard (1993), explicitly addressed concerns about the influence of information technologies on the discipline of geography. Sheppard argued that unintended consequences of Dobson's vision would include the privileging of certain ways of understanding the world over others, along with reinforcement of the power of well-financed interests over individuals and groups that lack equitable access to technology. Another commentator, John Pickles (1993), rejected the claim that the fulfillment of Dobson's vision would be a boon to geography. To the contrary, he argued, 'the spirit of Cartesianism, and claims to validity based on method alone no longer seem adequate to the task of building disciplines' (Pickles 1993, 454). These and subsequent critiques (e.g. Pickles 1995) mobilized widespread concern in the discipline about the implications of GIS for its disciplinary identity. Pickles, Sheppard and others did not contest that 'computers and electronic forms of database handling have become a common part of research and teaching practice' (Pickles 1993, 451). However, they did argue persuasively that if permitted to become unduly influential, GIS and (what some proponents had dubbed) GIScience threatened to turn geography into a discipline that conscientious geographers could not longer be proud of.

Debates about its desirability notwithstanding, GIS proliferated in North American academic geography between the mid-1980s and 1990s. The number of geography departments in the United States and Canada that claimed GIS as a specialization more than tripled from 1985 and 1995, from 67 to 203 departments. By comparison, increases in stated departmental specializations in remote sensing (56%; from 89 to 139 departments) and cartography (19%; from 146 to 174 departments) increased at much lower rates over the same period (Fryman 1996). Similarly, enrollments in formal courses in GIS offered by geography departments in US colleges and universities grew rapidly between 1992 (the first year GIS appeared as a distinct category) and 1994, from over 4000 to over 7000 enrollments, while enrollments in cartography, remote sensing, and computer mapping courses remained stable (Walker 1995 cited in Fryman 1996). The proliferation of GIS education in the 1990s was not limited to geography, or to North America. Morgan et al. (1996)

identified over 800 higher education institutions worldwide that offered at least one course on GIS, and Phoenix (1997, personal communication) estimated total enrollment in courses offered by all disciplines at about 40,000. By 2004, Phoenix estimated that approximately 7000 higher education institutions in over 150 countries were equipped with GIS technology, and that 'approximately 150,000 students a year, worldwide, [were] taking at least one course in GIS of having GIS exercises as part of another course' (Phoenix 2004, 34). An important early impetus for this proliferation was the National Center for Geographic Information and Analysis *Core Curriculum in GIS*, 'a detailed outline for a three-course sequence of 75 1-hr units' (Goodchild and Kemp 1992, 310). The original print version of the *Curriculum* was requested by over 1500 institutions and translated into several languages.

At the same time as the retrospective commentaries appeared in the *Professional Geographer* in 1993, a debate about the nature and scope of GIS took place on a listserv called 'GIS-L.' The debate consisted of 64 postings from 40 individuals over a 2-month period. In the hope of resolving the 'persistent ambiguity' about the meaning of GIS, Wright et al. (1997) performed a content analysis of the postings. They found a range of viewpoints, from participants who argued that 'GIS is a tool, i.e. the use of a particular class of software', to those who felt that GIS involves 'toolmaking, i.e. the advancement of the tools capabilities', to others who argued that GIS is a science, 'i.e. the analysis of the fundamental issues raised by the use of GIS' (Wright and others 1997, 346). The distinctions are important to discipline of geography, the authors argued, because GIS-related research is justifiable within graduate programs only if GIS is recognized as a substantive issue.

While acknowledging that the GIS-L debate did not yield a consensus among the participants, the authors clearly favored the 'GIS as science' viewpoint. They pointed out that Goodchild, who coined the term in 1992, claimed that GIScience combines the traditionally isolated fields of photogrammetry, remote sensing, geodesy, cartography, surveying, geography, computer science, spatial statistics, and other disciplines with interests in the generic issues of spatial data. GIScience thus represents a conception of GIS whose scope approaches that of Dobson's vision of automated geography, encompassing all or parts of several distinct but related disciplines. An even broader conception of the field, and one which provides more detail about the delineation and contents of its boundaries, is presented in the first edition of the *Geographic Information Science and Technology Body of Knowledge.*

GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY

The University Consortium for Geographic Information Science (UCGIS) is an alliance of over 80 universities (by 2007) dedicated to promoting

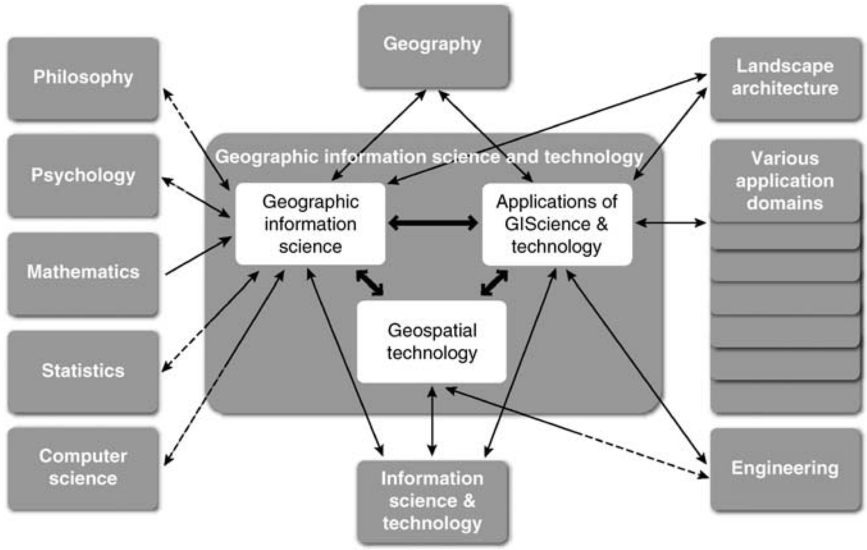

Fig. 1. The three sub-domains comprising the GIS&T domain, in relation to allied fields. Two-way relations that are half-dashed represent asymmetrical contributions between allied fields. Copyright: 2006 Association of American Geographers and University Consortium for Geographic Information Science. Used by permission. All rights reserved.

multidisciplinary research in GIScience. Although most UCGIS delegates share primary interest in research, the organization also promotes an education agenda. In 1997, UCGIS sponsored an 'education summit' in Bar Harbor, Maine. Among eight 'education challenges' identified at the summit was one that concluded that 'improving GIScience education requires the specification and assessment of curricula for a wide range of student constituencies' (Kemp and Wright 1997, 4). A Model Curriculum Task Force, chaired by Duane Marble, formed in 1998 to create a new undergraduate curriculum in GIS&T. In time, the plural 'Curricula' was adopted to emphasize the project's goal of supporting multiple curricular pathways tailored to the requirements of the diverse occupations and application areas that rely upon geospatial technologies. In 2003, the Task Force issued a 'Strawman Report' that presented an ambitious vision of how higher education should prepare students for success in a variety of professional roles and settings (Marble et al. 2003). One striking characteristic of the UCGIS Model Curricula vision is its broad and integrative conception of the 'geographic information science and technology' (GIS&T) knowledge domain. As illustrated in Figure 1, GIS&T encompasses three subdomains:

- *Geographic information science*, the multidisciplinary research enterprise that addresses the nature of geographic information and the application of geospatial technologies to basic scientific questions;

- *Geospatial technology*, the specialized set of information technologies that support data acquisition, data storage and manipulation, data analysis, and visualization of georeferenced data. Geospatial technologies include the Global Positioning System and comparable Global Navigation Satellite Systems in Russia and Europe; satellite, airborne, and shipboard remote sensing systems, and the data produced with such systems; and GIS and image analysis software tools, among others; and
- *Applications of GIScience and technology*, the increasingly diverse uses of geospatial technology in government, industry, academia, and by laypersons. The number and variety of fields that apply geospatial technologies is suggested in Figure 1 by the stack of 'various application domains'.

Figure 1 emphasizes the distinctness of GIS&T and related fields by depicting them as separate boxes. In fact, boundaries between fields overlap, sometimes with problematic consequences. One (of several) contentious boundary condition exists at the intersection of the discipline of geography and GIS&T. As described above, some geographers critique assumptions about the scientific basis of GIS, question its validity as a method of inquiry, and explore the moral implications of its use for surveillance and to facilitate warfare (e.g. Pickles 1995; Schuurman 2000; Sheppard 2005). As another example, the practice of professional surveying spans the boundaries of GIS&T and engineering. Unlike engineers and professional surveyors, who are licensed to practice by state governments in the United States, GIS practitioners are not subject to regulation (Joffe 2001). This has led to disputes among regulated and unregulated professionals about who is qualified to use new geospatial technologies such as GIS and global positioning system, and who is not.

Professional Debates

Concerns about the nature of GIS and its implications for professional practice are not unique to academic geographers, of course. A little more than a decade after the 'tool versus science' debate on the GIS-L listserv, a similar conversation took place on GEOXchange, a listserv for members of the Geospatial Information & Technology Association (GITA 2005). GITA's membership includes individuals and organizations involved with GIS applications in gas, electric, and water utilities, oil and gas pipelines, and telecommunications. Participants in the GEOXchange debate claimed variously that GIS is:

- A profession composed of individuals who are specifically trained and employed to perform GIS work;
- A discipline that combines perspectives of geography, computer science, and many other disciplines;
- A software tool used in many fields, often by individuals without specialized education; or
- A niche within organizations' larger information technology enterprises.

Like the debates among academic geographers (about which the utilities professionals seem to have been unaware), no consensus about the nature of GIS emerged either from the listserv thread or a subsequent panel discussion at an annual GITA conference. The 'geospatial industry white paper' that reported and reflected on the debate did conclude, however, that 'some mechanism needs to be enacted by the GIS industry to ensure that people who work in the geospatial disciplines have received broad education and training, can perform a variety of skills, and are competent at what they do' (GITA 2005, 4). 'After all', the GITA white paper claims, 'competency is the ultimate workforce attribute' (GITA 2005, 4).

ASSURING COMPETENCE

Workforce development experts define competence as 'the characteristics that lead to success on a job or a task' (Tubbs and Schulz 2006). Concerns about the availability of competent geospatial workers led the National Aeronautics and Space Administration (NASA) to sponsor an ambitious workforce development initiative beginning in 1997 (Gaudet et al. 2003, 21). In 2001, as part of that effort, NASA mobilized a team of workforce development specialists at the University of Southern Mississippi to develop a 'competency model' for geospatial professionals. The Geospatial Workforce Development Center (later reorganized as the Workplace Learning and Performance Institute) convened workshops involving representatives of 16 leading businesses, government agencies, and professional societies in the geospatial arena. Using focus group and group systems methodologies, researchers asked representatives to identify the key competencies and 'roles' that their employees or constituents were expected to play. Table 1 displays the resulting 'geospatial technology competency model' (GTCM) as a matrix that specifies that competencies are required for each of 12 identified roles.

Since the publication of the GTCM in 2003, it has become apparent that the diversity of applications of geospatial technologies and associated knowledge, skills, and abilities of GIS&T professionals defies generalization in a single simple matrix. As part of a project sponsored by the Department of Labor to define and communicate geospatial industry workforce demand, GITA, the Association of American Geographers (AAG), and the Wharton School of Business at the University of Pennsylvania assembled groups of 'thought leaders' representing industry, government agencies, and academia for two roundtable discussions in October 2006 and January 2007. Of the participants and other stakeholders who responded to an online survey, 62% agreed that technical competencies identified in the GTCM are inadequate. The project's 'Phase I Report' to the Department of Labor (GITA and AAG 2006, 30) concluded that the GTCM 'should be refined and updated.' DiBiase (2007) proposes that a more comprehensive set of technical competencies could be drawn from the *GIS&T Body of*

Table 1. The Geospatial Technology Competency Model (Gaudet et al. 2003) specifies which of 39 competencies are required for each of twelve roles performed by geospatial technology professionals. Competencies are grouped into four categories: technical, business, analytical, and interpersonal. Copyright: 2003 Urban and Regional Information Systems Association. Used by permission. All rights reserved.

Competencies	Roles	Application development	Coordination	Data acquisition	Data analysis	Data management	Management	Marketing	Project management	Systems analysis	Systems management	Training	Visualization
Technical	Ability to assess relationships among geospatial technologies		■				■	■		■	■	■	■
	Cartography			■	■					■			■
	Computer programming skills	■		■		■				■			■
	Environmental applications	■			■								■
	GIS theory and applications	■			■	■	■		■		■	■	■
	Geology applications				■								
	Geospatial data processing			■	■					■	■	■	■
	Photogrammetry	■		■	■								■
	Remote sensing theory and applications	■		■	■						■		■
	Spatial information processing	■		■	■							■	■
	Technical writing	■	■		■		■	■	■	■	■	■	■
	Technological literacy	■		■	■	■	■		■	■	■	■	■
	Topology				■								■
Business	Ability to see "big picture"	■	■			■	■	■		■	■	■	
	Business understanding		■				■		■				
	Buy-in / advocacy		■				■	■		■		■	■
	Change management	■	■		■	■	■	■	■	■	■	■	■
	Cost benefit analysis / Return on investment		■			■	■	■	■		■	■	■
	Ethics modeling				■		■	■	■		■	■	■
	Industry understanding	■	■				■	■				■	■
	Legal understanding		■										
	Organizational understanding		■				■				■		
	Performance analysis and evaluation			■			■		■	■	■	■	
	Visioning		■				■	■	■	■	■	■	
Analytical	Creative thinking	■	■	■	■	■	■	■	■	■	■	■	■
	Knowledge management		■		■		■		■		■	■	■
	Model building skills	■				■	■				■	■	■
	Problem-solving skills	■	■	■	■	■	■	■	■	■	■	■	■
	Research skill	■			■							■	
	Systems thinking	■					■			■	■	■	■
Interpersonal	Coaching		■				■					■	
	Communications	■	■	■	■	■	■	■	■	■	■	■	■
	Conflict management		■				■		■		■	■	
	Feedback skills	■	■	■	■	■	■	■	■	■	■	■	■
	Group process understanding		■				■		■		■	■	
	Leadership skills		■			■	■	■	■		■	■	■
	Questioning		■				■	■		■	■	■	
	Relationship building skills		■				■	■	■	■	■	■	
	Self-knowledge / self-management		■				■	■		■	■	■	

Knowledge (described below), and that specialized competency models should be developed for particular industry segments (for the same reasons that distinct GIS data models are developed for particular application areas). Specialized competency models are the end-state of the multiple curricular pathways envisioned as part of the UCGIS Model Curricula initiative.

The diversity of geospatial workforce needs is reflected in the variety of existing mechanisms intended to assure the competence of GIS&T professionals. These mechanisms include voluntary certification and obligatory state licensure of individual practitioners, as well as the accreditation of academic degree programs that prepare students to become licensed professionals. Each of these mechanisms represents a delineation of the scope of the GIS enterprise, and a claim that some would-be practitioners, and not others, are qualified to represent themselves as GIS&T professionals.

Professional Certification

Certification is the process by which organizations award credentials to individuals who demonstrate certain qualifications and/or competencies. Higher educational institutions confer academic certificates; professional societies and businesses operate professional certification programs. Two US organizations – the American Society for Photogrammetric Engineering and Remote Sensing (ASPRS) and the GIS Certification Institute (GISCI) – currently operate voluntary certification programs in the GIS&T field. In Australia, the Spatial Sciences Institute offers a professional certification similar to GISCI's. In Great Britain, the Royal Geographical Society operates a Chartered Geographer program that requires applicants to document experience, education, and evidence of continuing professional development. Barnhart (1997) identifies three types of professional certification: portfolio-based, competence-based, and curriculum-based. The difference between the competence-based and portfolio-based certification is illustrated in the ASPRS and GISCI programs.

ASPRS CERTIFICATION PROGRAMS

The ASPRS established voluntary certification program for professional photogrammetrists in 1978. Two additional certifications, 'Certified Mapping Scientist-Remote Sensing' and 'Certified Mapping Scientist-GIS/LIS', were added in 1988. Originally, applicants submitted an application, a fee, and four personal references for review by a volunteer panel of certified professionals. A proctored examination was added to the certification requirements in 1999. In 2003, ASPRS added a second tier of certifications for photogrammetry, remote sensing, and GIS/LIS 'Technologists.' More recently, ASPRS expanded their programs again to include students in

Table 2. Proportion of questions in ASPRS Mapping Scientist-GIS/LIS certification examination, by knowledge area (Burtch 2006).

Knowledge area	Percentage of questions
Mathematics and science	14–16
Engineering surveying	5–6
Physics	7–9
Imaging	18–20
Photogrammetry	10–13
Geographic information systems (GIS)	21–23
Ethics and general knowledge	15

ASPRS, American Society for Photogrammetric Engineering and Remote Sensing.

approved higher education degree programs who, if they pass an examination and peer-review of credentials, become 'provisionally certified' until they amass the necessary experience for full certification (Renslow 2006). To remain active, professionals must submit applications to become re-certified every 5 years; technologists are expected to re-certify every 3 years.

Six years of total experience (including 3 years of professional experience) is required for ASPRS certification as a photogrammetrist or mapping scientist. Certified technologists document at least 3 years of total experience (including 2 years of professional experience). Applicants must confirm that they will comply with a Code of Ethics. In addition, applicants to the professional certification program must pass a 4-hr, 100-question multiple-choice examination. Examinations for technologists last 2 hr, and include 50 questions. Applicants are permitted to consult one hard-bound reference book of their choice during the examination. The content of examinations varies by specialty. The topical distribution of questions in the ASPRS Mapping Scientist-GIS/LIS examination consists appears in Table 2. The distribution reflects ASPRS' belief that a certified 'mapping scientist' who specializes in GIS ought to be able to demonstrate mastery of a broad, multidisciplinary body of knowledge.

By 2006, ASPRS had certified some 1400 photogrammetrists. Eight hundred of these remain active, representing about 40% of the total US workforce (Renslow 2006). However, only 54 Certified Mapping Scientists and three Certified GIS/LIS Technologists were listed as active at the ASPRS Web site as of May 2008. For many GIS practitioners, it appears that the perceived risk of failing ASPRS' challenging examination outweighs the perceived benefit of voluntary certification.

ASPRS' programs exemplify competence-based certification, in which candidates must demonstrate their mastery of a common body of knowledge within their profession by examination. In contrast, GISCI's geographic information systems professional (GISP) certification program is portfolio-based, requiring individuals only to document relevant qualifications at specified levels of achievement.

GIS CERTIFICATION INSTITUTE

After over 5 years of planning, a spin-off of the Urban and Regional Information Systems Association (URISA) called GISCI began accepting applications in 2004. Individuals are certified as GISPs by earning a requisite number of 'achievement points'. Point values are defined for achievements related to:

- Education: the minimum achievement is equivalent of a bachelor's degree earned in any field, in addition to some specialized education in GIS&T;
- Experience: the equivalent of four years' experience as a GIS practitioner in a professional setting; and
- Contributions to the profession, including documented service to professional societies, presentations and publications in professional conferences or periodicals, etc.

Applicants must also agree to comply with a Code of Ethics and Rules of Conduct. No examination is required. GISCI certified 535 GISPs in its first year and 2193 through April 2008. Because they calculate point totals themselves as part of the application process, there is little suspense about the outcome of the GISCI certification decision. The greater popularity of portfolio-based certification may be due to the fact that applicants face little risk of being embarrassed the outcome of the application process.

The URISA committee that planned the GISCI certification program was mindful of the argument that GIS certification needs to attract widespread participation if it is to influence professional practice (Obermeyer 1993). The committee adopted a portfolio-based approach as a way to lower barriers to participation in what some committee members envisioned as essentially a professional development program. While GISCI certification does little to ensure professional competence (Somers 2004), it apparently is succeeding in building a community of practitioners who subscribe to a professional development strategy based on ethical practice, lifelong learning, and participation in professional organizations.

Contributors to the debate described in the GITA (2005) white paper criticize GISCI certification for defining GIS too broadly to usefully evaluate competence in particular application areas, and for failing to mandate educational standards. The latter complaint epitomizes the common confusion of certification and accreditation. It also highlights a fundamental difference in values between the practitioners and employers who participated in the GITA listserv debate and contributors to the 'Tool vs.

Science' debate on GIS-L, many of whom were affiliated with academic departments of geography. Professionals working in industry and government agencies prize competence and accept regulatory mechanisms meant to assure a competent workforce. However, those who work as faculty members in higher education institutions value academic freedom most highly and are averse to regulations that may threaten it.

Licensure

Land surveying and photogrammetry are two professions that intersect the GIS&T domain and that are subject to state licensure in the United States. All 50 states have legislation establishing licensure review boards that oversee application procedures and examinations and confer licenses to practice professional surveying. Bruce Joffe (2001) explains that although the laws vary, most resemble the 'Model Law' promulgated by the National, Council of Examiners for Engineering and Surveying (NCEES 2001). The Model Law was revised in 2000 in response to recommendations by a Task Force of industry representatives concerned with bounding the scope of licensed practice. In addition, a set of 'Model Rules' was developed to advise legislatures and licensure boards that mapping activities should be excluded from definitions of surveying practice. Still, Joffe reports that a literal interpretation of most of state definitions of survey practice would require that most professional uses of geospatial technologies, including GIS software, be supervised by licensed surveyors. And while many surveyors may acknowledge that much of GIS&T is beyond the scope of their licensed practice, nothing in the state legislation permits such a flexible interpretation (Joffe 2001).

To date, instances of legal actions against individuals accused of practicing GIS without a license are few and anecdotal (e.g. Zimmer 2003). However, a recent federal court case challenged the way in which the US government has implemented a policy that guides its procurement of mapping products and services (MAPPS et al. vs. United States 2006). The policy, known as the *Brooks Act*, stipulates that when federal government agencies request bids for engineering and architectural and engineering (A-E) services from private sector vendors, they must take vendors' qualifications into account, rather than simply awarding contracts to the lowest bidder. Included in the *Brooks Act's* scope of A-E services is professional surveying, the practice of which (as defined in state licensure legislation) includes 'mapping services'. The lawsuit, filed by the Management Association of Private Photogrammetric Surveyors (MAPPS) and three kindred engineering societies, objects to the current practice of the government's Federal Acquisitions Regulation (FAR) Council, whose interpretation of 'mapping services' has excluded:

> . . . mapping services that are not connected to traditionally understood or accepted architectural and engineering activities, are not incidental to such architectural and engineering activities, or have not in themselves traditionally

> been considered architectural and engineering services shall be procured [on the basis of price as well as technical qualifications of bidders for federal contracts]. (FAR Council 1991)

The MAPPS litigation insisted that the FAR Council adopt qualifications-based selection in the procurement of any and all mapping services, as a literal reading of the *Brooks Act* requires. Implicit in the suit is a claim that the best-qualified bids will be from registered A-E firms in which licensed professionals supervise the provision of mapping services, ostensibly as a means to protect public health, safety, and welfare.

The ultimate objective of state licensure is to protect the public from harm caused by the incompetent providers of certain goods and services. In the interest of such protection, US states have enacted licensure laws for many professions, including medicine, law, and some engineering disciplines. Francis Harvey (2003) suggests numerous scenarios in which public safety might be jeopardized by incompetent or malicious use of geospatial technologies. He also points out, however, that leading professional organization of computer engineers rejected proposal to certify or license practitioners because no test could ensure that public health and welfare would never be endangered. While the general question of whether licensure is an effective means of protecting public health, safety, and welfare is moot in the context of architecture and engineering, it remains debatable in the context of GIS&T. Curt Sumner, executive director of the leading professional society of land surveyors, suggested chillingly that 'it may take a case in which harm is caused on a large scale before the matter can be rationally discussed' (Sumner 2007, 71).

Professional societies representing constituencies other than photogrammetric firms interpreted the MAPPS suit as an attempt to claim authority over substantial portion of professional practice in the GIS&T domain. Their reaction was swift and fierce. In cooperation with URISA, GISCI, GITA, and UCGIS, AAG played a leading role in preparing an *amicus curiae* (friend of the court) brief that argued that:

> Public safety is not compromised . . . when the government procures mapping services that are not traditionally performed by or associated with A-E firms, that do not relate to legal rights in and to real property, and that require subject matter expertise that architects, engineers, and surveyors do not possess. (AAG et al. 2007)

While awaiting the court's decision, both the plaintiffs and the *amici* launched aggressive public relations campaigns. In a document entitled 'QBS Litigation: Myth vs. Fact', MAPPS denied that the intent of its suit was to restrict federal mapping contracts to registered A-E firms, or to 'control the GIS profession' as the *amici* accused (MAPPS 2007, 4). An editorial in AAG's monthly newsletter that explained its opposition to the suit was titled 'The Plan to Hijack Mapping' (Richardson 2007). Both organizations solicited contributions from members to help offset their legal expenses.

On June 15, 2007, the US District Court for the Eastern District of Virginia found against MAPPS and its fellow plaintiffs, in part because they failed to demonstrate that their constituents were harmed by FAR procurement policies. While the case was decided on the matter of standing, rather than on its merits, the court did note that:

> . . . the record unambiguously reflects that the provision of 'mapping' services in the modern marketplace includes a much broader scope of work than the traditional mapping work of land surveyors. (Ellis 2007)

Reflecting on the suit and its outcome some months later, Sumner (2007, 71) speculated that opposition to the lawsuit may have been 'intended to incite the GIS and computer mapping industry to become more active in the political arena.' Although the MAPPS lawsuit was unsuccessful, there is no doubt that it and kindred professional organizations will continue to lobby Congress and state governments on behalf of legislation that benefits their constituents. As the geospatial industry grows increasingly large and lucrative, more and more livelihoods are potentially affected by government regulations that determine who is eligible to practice GIS, and by extension who is eligible to teach it. It remains to be seen whether AAG, whose constituency consists largely of academic geographers, will continue to prevail in the political struggle against the regulation of GIS&T in the current age of accountability.

This section has considered efforts by educators and researchers, workforce development specialists, and practitioners and their employers to delineate the scope of the GIS&T enterprise. Implicit in these scopings is the fact that each stakes out a territory that includes some individuals and professional practices, and excludes others. GIS&T need not be rarified as a professional enterprise, of course; laypersons use geospatial technologies for many purposes, including entertainment and artistic expression, and for formal and informal community service. The emphasis on exclusive delineations in this article responds to the potential of GIS&T professions to provide sustainable livelihoods to many workers in the United States and elsewhere, and to the urgent need to educate future workers effectively to ensure their competitiveness in an increasingly global labor market. Although no consensus exists about the scope of the field, the broad and inclusive scope of GIS&T proposed by UCGIS seems best suited to prepare educators to help their students make sense of the field. In particular, the perspective of GIS&T as an intersection of regulated and unregulated professions also helps explain the recent conflict among these constituents. Turning from the boundaries of the GIS&T domain, the following section considers its contents.

The Content of GIS&T

Central to the UCGIS Model Curricula vision is a comprehensive 'body of knowledge' that specifies what current and aspiring geospatial professionals need to know and be able to do. Following over 7 years of deliberations involving more than 70 contributors and reviewers, the Association of American Geographers published the first edition of the *GIS&T Body of Knowledge* in 2006 (DiBiase et al. 2006). Like the bodies of knowledge included in recent *Computing Curricula* (ACM/IEEE-CS Joint Task Force 2001), the *GIS&T Body of Knowledge* represents the GIS&T knowledge domain as a hierarchical list of knowledge areas, units, topics, and educational objectives. The 10 knowledge areas and 73 units that comprise first edition are shown in Table 3. Twenty-six 'core' units (those in which all graduates of a degree or certificate program should be able to demonstrate some level of mastery) are shown in bold type. Not shown are the 329 topics that make up the units, or the 1660 education objectives by which topics are defined.

One of the most extensive of the 10 knowledge areas in the *GIS&T Body of Knowledge* is 'analytical methods' (AM). Twelve units, three of which are core units, comprise knowledge area AM (Table 3). Fifty-nine topics, defined in terms of 281 educational objectives, comprise the 12 units. In many cases, objectives span the six 'cognitive levels' and first three 'knowledge types' identified in the *Taxonomy of Education Objectives* (Anderson and Krathwohl 2001). Also provided at the end of the knowledge area are references to 34 'key readings'. An example core unit – AM4 – appears in Table 4.

USES OF THE GIS&T BODY OF KNOWLEDGE

Like their counterparts in computer science and other fields, the UCGIS Model Curricula Task Force originally conceived of the *GIS&T Body of Knowledge* as a basis for curriculum planning. After publication of the Task Force's 'Strawman Report' (Marble et al. 2003), however, other needs became increasingly apparent, including:

- Program evaluation: assessment instruments derived from *GIS&T Body of Knowledge* will help academic programs determine their standing and performance relative to a comprehensive set of community-authored educational objectives.
- Program articulation: articulation agreements ensure that credits earned in one educational institution count toward corresponding certificate and degree programs at another institution. Institutions that agree to specify course topics and objectives consistent with the *GIS&T Body of Knowledge* may find it easier to execute such agreements.
- Curriculum revision: the first and subsequent editions of the *GIS&T Body of Knowledge* will be useful in helping faculties to identify the topics, objectives, and future staff specializations needed to ensure that their curricula reflect the breadth and depth of the evolving GIS&T field.

Table 3. Knowledge areas and units comprising the first edition of the *GIS&T Body of Knowledge*. Core units are indicated with bold type. Copyright: 2006 Association of American Geographers and University Consortium for Geographic Information Science. Used by permission. All rights reserved.

Knowledge area analytical methods
Unit AM1: academic and analytical origins
Unit AM2: query operations and query languages
Unit AM3: geometric measures
Unit AM4: basic analytical operations
Unit AM5: basic analytical methods
Unit AM6: analysis of surfaces
Unit AM7: spatial statistics
Unit AM8: geostatistics
Unit AM9: spatial regression and econometrics
Unit AM10: data mining
Unit AM11: network analysis
Unit AM12: optimization and location-allocation modeling

Knowledge area conceptual foundations
Unit CF1: philosophical foundations
Unit CF2: cognitive and social foundations
Unit CF3: domains of geographic information
Unit CF4: elements of geographic information
Unit CF5: relationships
Unit CF6: imperfections in geographic information

Knowledge area cartography and visualization
Unit CV1: history and trends
Unit CV2: data considerations
Unit CV3: principles of map design
Unit CV4: graphic representation techniques
Unit CV5: map production
Unit CV6: map use and evaluation

Knowledge area design aspects
Unit DA1: the scope of GIS&T system design
Unit DA2: project definition
Unit DA3: resource planning
Unit DA4: database design

Knowledge area data manipulation
Unit DN1: representation transformation
Unit DN2: generalization and aggregation
Unit DN3: transaction management of geospatial data

Knowledge area geocomputation
Unit GC1: emergence of geocomputation
Unit GC2: computational aspects and neurocomputing
Unit GC3: cellular automata models
Unit GC4: heuristics
Unit GC5: genetic algorithms
Unit GC6: agent-based models
Unit GC7: simulation modeling
Unit GC8: uncertainty
Unit GC9: fuzzy sets

Knowledge area geospatial data
Unit GD1: earth geometry
Unit GD2: land partitioning systems
Unit GD3: georeferencing systems
Unit GD4: datums
Unit GD5: map projections
Unit GD6: data quality
Unit GD7: land surveying and global positioning system
Unit GD8: digitizing
Unit GD9: field data collection
Unit GD10: aerial imaging and photogrammetry
Unit GD11: satellite and shipboard remote sensing
Unit GD12: metadata, standards, and infrastructures

Knowledge area GIS&T and society
Unit GS1: legal aspects
Unit GS2: economic aspects
Unit GS3: use of geospatial information in the public sector
Unit GS4: geospatial information as property
Unit GS5: dissemination of geospatial information
Unit GS6: ethical aspects of geospatial information and technology
Unit GS7: critical GIS

Table 3. *Continued*

Unit DA5: analysis design Unit DA6: application design Unit DA7: system implementation **Knowledge area data modeling** Unit DM1: basic storage and retrieval structures **Unit DM2: database management systems** **Unit DM3: tessellation data models** **Unit DM4: vector and object data models** Unit DM5: modeling three-dimensional, temporal, and uncertain phenomena	**Knowledge area organizational and institutional aspects** Unit OI1: origins of GIS&T Unit O2: managing the GIS operations and infrastructure Unit OI3: organizational structures and procedures Unit OI4: GIS&T workforce themes **Unit OI5: institutional and interinstitutional aspects** **Unit OI6: coordinating organizations (national and international)**

- Professional certification: the *GIS&T Body of Knowledge* is used by the GISCI to adjudicate applicants' point claims associated with educational achievement.
- Program accreditation: although many academic programs related to GIS&T are not subject to subject-specific accreditation, the US Geospatial Intelligence Foundation (USGIF) has established a Geospatial Intelligence Academy that will 'establish curriculum guidelines and accreditation standards and processes for geospatial intelligence academic courses and certificate programs' (US Geospatial Intelligence Foundation 2005). The USGIF panel charged with defining the Academy's guidelines and standards relies upon the *GIS&T Body of Knowledge* to help specify its curriculum standards.
- Employee screening: in unprecedented breadth and detail, the *GIS&T Body of Knowledge* defines the knowledge and skills that well-educated professionals should possess. Job descriptions and interview protocols may be derived from these objectives.

Most important, perhaps, is the potential of the *GIS&T Body of Knowledge* to foster consensus about the broad scope and multidisciplinary nature of the field. In relation to the MAPPS case, Sumner (2007, 71) observed that 'not enough communication has occurred among the parties to provide an understanding of why any of them act and/or react with such vitriol.' Cooperative preparation of subsequent editions of the *GIS&T Body of Knowledge* could be an effective vehicle for communication among the societies and their constituents. One potential benefit of such cooperation is a more coherent image of the field, which might in turn render it a more attractive career aspiration for students. Surely, this is an outcome that all constituents of the GIS&T field would welcome.

Table 4. Topics and educational objectives comprising core unit AM4: basic analytical operations, from the analytical methods knowledge area of the first edition of the *GIS&T Body of Knowledge*. Copyright: 2006 Association of American Geographers and University Consortium for Geographic Information Science. Used by permission. All rights reserved.

Unit AM4 basic analytical operations (*core unit*)
This small set of analytical operations is so commonly applied to a broad range of problems that their inclusion in software products is often used to determine if that product is a 'true' geographic information system (GIS). Concepts on which these operations are based are addressed in Unit CF3 Domains of geographic information and Unit CF5 Relationships.

Topic AM4-1 buffers
- compare and contrast raster and vector definitions of buffers
- explain why a buffer is a contour on a distance surface
- outline circumstances in which buffering around an object is useful in analysis

Topic AM4-2 overlay
- explain why the process 'dissolve and merge' often follows vector overlay operations
- explain what is meant by the term 'planar enforcement'
- outline the possible sources of error in overlay operations
- exemplify applications in which overlay is useful, such as site suitability analysis
- compare and contrast the concept of overlay as it is implemented in raster and vector domains
- demonstrate how the geometric operations of intersection and overlay can be implemented in GIS
- demonstrate why the georegistration of datasets is critical to the success of any map overlay operation
- formalize the operation called map overlay using Boolean logic

Topic AM4-3 neighborhoods
- discuss the role of Voronoi polygons as the dual graph of the Delaunay triangulation
- explain how the range of map algebra operations (local, focal, zonal, and global) relate to the concept of neighborhoods
- explain how Voronoi polygons can be used to define neighborhoods around a set of points
- outline methods that can be used to establish non-overlapping neighborhoods of similarity in raster datasets
- create proximity polygons (Thiessen/Voronoi polygons) in point datasets
- write algorithms to calculate neighborhood statistics (minimum, maximum, and focal flow) using a moving window in raster datasets

Topic AM4–4 map algebra
- describe how map algebra performs mathematical functions on raster grids
- describe a real modeling situation in which map algebra would be used (e.g. site selection, climate classification, least-cost path)
- explain the categories of map algebra operations (i.e. local, focal, zonal, and global functions)
- explain why georegistration is a precondition to map algebra
- differentiate between map algebra and matrix algebra using real examples
- perform a map algebra calculation using command line, form-based, and flow charting user interfaces

Conclusion

The starting point for this article was the observation that GIS education is not guided by a disciplinary consensus about the nature and content of the field. Consensus among academic geographers remains elusive, even after 25 years of debate. Although many geographers rejected the claim that automated geography would change their discipline for the better, there is little question that the discipline has changed in the United States at least. By 2000, Reginald Golledge, then president of the Association of American Geographers, predicted that the ways in which the discipline responds to increasing demand for professional certificate and degree programs in GIS and GIScience would 'determine the viability, and ultimately the fate of geography' (Golledge 2000, 8).

Consensus does seem to exist among practitioners and employers about the paramount importance of competence. A variety of regulatory mechanisms exist to assure competent professional practice. Some professions, including land surveying and photogrammetry, are subject to mandatory state licensure in the United States. Others are beginning to embrace voluntary portfolio-based certification. Correspondingly, some university degree programs that prepare future geospatial professionals are subject to accreditation while others are not. Broadly conceived, the GIS&T field occupies the intersection of accredited and non-accredited disciplines, regulated and unregulated professions, and old and new technologies. No wonder the field is contentious and confusing.

I have proposed that the *GIS&T Body of Knowledge* could serve as a vehicle for consensus-building and cooperation among the competing interests that comprise the field. This echoes the recommendation of the Committee on Beyond Mapping of the National Research Council (NRC 2006). I have suggested that this would benefit the enterprise, and society, by fostering a more coherent image of the field that renders it more attractive to students who seek meaningful and rewarding careers. The 10 knowledge areas, 73 units, 329 topics, and 1660 educational objectives that make up the *GIS&T Body of Knowledge* should be useful to educators in many disciplines and institutions. These claims, like Dobson's 25 years ago, are sure to be disputed. As in the 'canon wars' in US higher education in the late 1980s, there will be debates 'between those who defend the idea of a distinct body of knowledge and texts that students should master and those who focus more on modes of inquiry and interpretation' (Donadio 2007, 16). Fortunately, the conception of the GIS&T field as an intersection of competing yet complementary interests easily accommodates such debates. In this sense, it is comparable to the field of education. Lee Shulman, former president of the Carnegie Foundation for the Advancement of Teaching, observed in 1988 that:

> . . . education is not itself a discipline. Indeed, *education is a field of study* [author's emphasis], a locus containing phenomena, events, institutions, problems, persons,

> and processes, which themselves constitute the raw material for inquiries of many kinds. The perspectives and procedures of many disciplines can be brought to bear on the questions arising from and inherent in education as a field of study. (p. 5)

The fact that our field is contested by a variety of disciplines and professions is a testament to its value and importance to society. GIS educators will serve their students best, I suggest, by helping them make sense of the full scope of the diversity and controversy that characterize GIS&T. Some academic debates, after all, are fierce because very much is at stake.

Afterword

As explained above, GIS&T is a broad and inclusive conception of a field. The *GIS&T Body of Knowledge* was meant to reflect perspectives of academics and practitioners from a variety of cognate disciplines and professions. A weakness of the first edition of the *GIS&T Body of Knowledge* is that contributors included too many academicians (especially geographers) and too few practitioners (especially photogrammetrists and surveyors). Hopefully the planned effort to create a second edition of the *GIS&T Body of Knowledge* will be more successful in attracting a more representative body of contributors. Meanwhile, Felus' (2007) analysis of the pertinence of the *GIS&T Body of Knowledge* to surveying education is heartening:

> While DiBiase et al. (2006, 182) was not developed by surveyors or for surveyors, with minor adjustments, this treatise correctly identifies the core body of knowledge in GIScience&T pertinent to surveying education.

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Short Biography

David DiBiase directs the Dutton e-Education Institute at the Pennsylvania State University, University Park, PA, USA. Also as a senior lecturer of geography, he leads Penn State's Online Certificate and Master's Degree programs in GIS. David is author of the open online textbook *Nature of Geographic Information* (http://natureofgeoinfo.org). While serving as chair of the University Consortium for Geographic Information Science's Education Committee from 2004 to 2006, he led a team of editors and contributors who completed the first edition of the *Geographic Information Science and Technology Body of Knowledge*, which is published by the Association of American Geographers. David's research publications include empirical studies of instructor and student experiences in distance education. He earned bachelor's and master's degrees in cartography from the University of Wisconsin-Madison and is certified as a Mapping Scientist – GIS/LIS by ASPRS and as a GIS Professional by the GIS Certification Institute.

Note

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