The Association of American Geographers

Masters in Geographic Information Systems Programs in the United States: Professional Education in GIS and Geography

Journal:	*The Professional Geographer*
Manuscript ID:	Draft
Manuscript Type:	Regular Manuscript
Key Words:	GIS Education, Master's Degree Programs, Master's in GIS, Professional Education, Soft Skills

Masters in Geographic Information Systems Programs in the United States: Professional Education in GIS and Geography

Abstract

This article examines the rise of Master's degree programs in Geographic Information Systems (MGIS) in the United States. We reviewed MGIS program websites and conducted thirteen in-depth interviews with program directors. Results show the range and complexity of programs in terms of mode of delivery, who teaches in the program, and how a program engages with the geospatial industry. The diversity of MGIS programs, their difference from traditional programs, and their focus on professional education all point toward a new style of degree program that challenges us to think differently about the future of graduate education in geography and GIS. *GIS Education, Master's Degree Programs, Master's in GIS, Professional Education, Soft Skills,*

Introduction

The fastest growing and largest component of graduate education in the United States in the 21st century is the master's degree. According to a report in the *Washington Post* the graduation rate of master's degrees increased sixty-three percent from 2000-2012, which exceeded the growth of bachelor's degrees by eighteen percent (Anderson 2013). As Katherine Newman, Dean of Arts and Sciences at John Hopkins University notes, "Once upon a time, American industry would have expected people to learn on the job. Increasingly, employers are looking to universities." (Anderson 2013, 1). While business and education degrees accounted for more than half of all master's degrees from 2000-2012, other programs are proliferating, including geographic information systems (GIS). This rise in GIS degrees may not surprise geographers, who frequently point to the Department of Labor's designation of geospatial technologies as a high growth industry.[1] This is a good sign for geography and indicates a growing demand for geographic insights in many different fields. At the same time, the demand seems to be focused on student's that are educated somewhat differently than traditional bachelor's, master's and doctoral degrees.

In 2011, however, a less publicized federal change to the status of GIS occurred that will have long term implications for GIS education: the National Center for Education Statistics changed the Classification of Instructional Programs (CIP) designation for Geographic Information Science and Cartography (45.0702) to a Science, Technology, Engineering, and Math (STEM) program.[2] This made Geographic Information Science the first STEM based

CIP in the social sciences. The fast rise of Master's in GIS programs (MGIS) points toward a change occurring in geography graduate education and reflects the driving need for high technology skills in the information economy. In 2012 the Association of American Geographers' (AAG) *Guide to Geography Programs in the Americas 2010-2011* identified 25 MGIS programs. As of 1 January 2014 our research, however, has documented forty-six such programs in the United States, nearly all of them initiated after 2000 (Table 1). Whereas the AAG seeks to show only geography departments in their publication, we sought to document all MGIS programs in the United States. There are considerable differences among MGIS programs in terms of size, scope, and approaches, but all seem to point toward a need for a new type of geographic education, one geared toward professional education. Here, student outcomes are gauged by placement with business, government, and non-profit (BGN) organizations rather than by placement as professors at research and teaching universities.

This paper documents the scope, similarities, and differences among the MGIS programs in the United States. We argue that MGIS programs are ushering in a new era of professional education in geography graduate programs. Professional education incorporates "soft" skills, or general business skills, into the curriculum and impacts MGIS student body make-up, mode of educational delivery, student outcomes, and placement. The remainder of this paper is organized around three sections. First, we discuss the methods used to survey and investigate MGIS programs in the United States. Second, we review GIS and professional education literature with an emphasis on the geospatial industry. Finally, we report results from our research on MSGIS programs in the U.S. and speculate on the implications of these findings for graduate education in geography.

Methods

We began our research by determining the number and locations of MGIS programs in the United States as of 2014. To do this we used the Program Specialties table in the *Guide to Geography Programs in the Americas 2010-2011* (AAG 2012, 250) as a baseline that was then updated and supplemented with MGIS program information from department and university websites. While all information for each MGIS program could not be obtained for our final tabulations, we included the following categories in our search: name of university; name of program; program URL; date started; online program (and if so did it require an residential component); campus program (i.e., residential); program length (in years); number of faculty in the department; program director's name and department standing; number of teachers in the MGIS program; number of regular faculty teaching in the program; ratio of total department faculty to MGIS faculty; number of adjunct faculty in MGIS; ratio of regular to adjunct faculty in program; master's thesis or master's project; GRE required; cost; and, number of credit hours. Our project focused only on master's degree programs and did not examine graduate certificates which many of the 46 MGIS units also offered.

While the website survey provided basic program information for analysis, idiographic data were derived from in-person and phone interviews with thirteen MGIS program directors. Our interview selection process was based on three criteria. First, we needed the selection to reflect the diversity of MGIS programs in the United States. Diversity here meant representing MGIS programs from both doctoral granting units as well as those where the master's was the highest degree offered. Second, there was a need to represent both online and in-person programs and to include both public and private universities. Third, we wanted a geographically dispersed selection of programs from across the country and therefore included

ones from large metropolitan areas in addition to those from smaller cities. Interviewees and their institutions are not referenced in this document in accordance with the approved human subject procedures from the Institutional Review Board at the University of _____ (left blank for blind review).

The interview consisted of fifteen questions and lasted between forty-five minutes to one hour. All interviews were taped and transcribed. Four categories of questions were included in the interviews. Overview questions sought to provide a basic understanding of the MGIS program. Staffing questions focused on who teaches in the program. Additional questions explored who constitutes the student body. A single business model question sought to query how the program was funded, an element that has broader implications for professional education and how the program operates on campus. A third category of questions addressed professional relations with the goal of probing the connections between the MGIS program and the professional GIS community. Finally, education and curriculum questions queried how MGIS programs dealt with soft skills and how professional education was carried out.

Literature Review

How GIS is taught has received much attention in the last two decades. From the first GIS textbook in the 1980s (Burrough 1986), to the establishment of the National Center for Geographic Information Analysis (NCGIA) core curriculum (Kemp and Goodchild 1991, 1992), to more recent volumes examining the role of teaching GIS in higher education (Unwin et al. 2012), the pedagogy of GIS remains a central concern to the profession. This research has focused on the history of GIS education (Tate and Unwin 2009), roles of GIS in higher education (Sinton 2009) and in K-12 and secondary education (Kerski, Demirci, and Milson

2013; Baker 2005; Baker and Bednarz 2003; Myer et al. 1999), continuing education and certificate programs (Wikle 1998), interdisciplinary cooperation in GIS education (Kawabata et al. 2010), how GIS promotes spatial thinking skills (Lee and Bednarz 2009), and the core competencies of GIS knowledge and skills (Schulze, Kanwischer, and Reudenbach 2013). Within this pedagogic literature there is a significant emphasis on professional education. This can be traced back to the establishment of the NCGIA core curriculum, when Kemp and Goodchild (1991, 125) argued, "The challenge in the development of this curriculum is a careful balancing between the needs of the job market and the recognition of GIS as a new opportunity for advancing spatial research and analysis." This challenge has been echoed by Foote et al. (2012, 6) when they state,

> There was, and to an extent this remains today, a very strong 'professional' interest necessitating the development of professional education in systems not initially designed to provide it. Again, this is an example of what is rapidly becoming a more general issue for educators as the public rightly demands a greater and greater level of accountable professionalism in almost all walks of life.

Similarly, Susanna and Robert McMaster (2012, 182) posit that a fundamental research issue in GIS education is addressing the following question: "What exactly is the nature of the distinction between academic and professional training for geospatial technologies?" Much of what is written about teaching GIS in higher education either focuses on the undergraduate level or does not distinguish between undergraduate, master's, and doctoral education (Songer 2010; Lloyd 2001; Kemp, Goodchild, and Dobson 1992; Goodchild 1985). For faculty in the U.S., the focus of doctoral education in geography emphasizes preparation for

research careers in academia, although doctoral students often express the desire for broader career options (Monk, Foote, and Schlemper 2012). In those U.S. geography departments where the master's is the terminal degree the expectations of faculty and students appear more aligned; in these situations the desired outcomes are more likely to be professional placement outside of the academy (Monk, Foote, and Schlemper 2012). In the United Kingdom, New Zealand, and Australia there has been an increasing value placed on defining what is *mastersness* (Quality Assurance Agency for Higher Education 2013; Warring 2011). According to the Quality Assurance Agency for Higher Education (2013), facets of mastersness include abstraction, depth of learning, research and enquiry, complexity, autonomy, unpredictability, and professionalism. Realigning the master's degree to better-fit career outcomes outside of academia requires the integration of masterness with skills gleaned through professional education (autonomy, unpredictability, and professionalism) (cf. Solem, Foote, and Monk 2013).

In a survey that compared the skills used by professional geographers with the anticipated demand for those skills by employers, Solem, Cheung, and Schlemper (2008) found that demand for general business skills, or "soft" skills, was universal across sectors. Further, Solem, Cheung, and Schlemper (2008) surveyed 280 working professional geographers and asked them to rank 49 skill areas that were categorized as either geographic or general. Results from that survey showed that not only are "general skill areas are applied more frequently than any area of geographic skill" (Solem, Cheung, and Schlemper 2008, 366), but also that the top eleven skills performed were always or very often soft skills. These top skills included (in rank order) time management, writing, critical thinking, problem solving, computer and technology,

creative thinking, self-awareness, visual presentation, ethical practice, information management, and public speaking.

Carrivick (2011, 483) points out that master's programs need to "harmonize the traditional intellectual competencies of the 'academy' with vocational training and professional development." He further suggests that the perceptions held by academics and employers differ on what skills are most important, leading to the need for external accreditation reviews in order to align what skills are taught. While most MGIS programs are not subject to disciplinary accreditation (DiBiase 2003), the United States Geospatial Intelligence Foundation recently established the *Collegiate Geospatial Intelligence Certificate Accreditation Guidelines* (USGIF 2013) which was based on both the *Geographic Information Science and Technology Body of Knowledge* (BoK)(DiBiase et al. 2006), and the United States Department of Labor Employment and Training Administration's Geospatial Technology Competency Model (DOLETA GTCM) (DOLETA 2010). The USGIF uses the BoK and GTCM to define its curriculum and accreditation standards.

The BoK defines the domain of Geographic Information Systems and Technology (GIS&T) as a "hierarchical list of knowledge areas, units, topics, and educational objectives" (DiBiase et al. 2007, 115). Whereas the BoK focuses on fundamental skills and subject matter related to GIS&T, the GTCM places academic and technical competencies alongside workplace and personal effectiveness competencies. Competency here refers to "the capability of applying or using knowledge, skills, abilities, behaviors, and personal characteristics to successfully perform critical work tasks, specific functions, or operate in a given role or position" (Ennis 2008, 4-5). As DiBiase et al. (2007, 2010) argue, one of the most important potential uses for the BoK and the GTCM "may be to self-assess how education and training

curricula align with workforce needs" (DiBiase et al. 2010, 70). The rise of MGIS programs occurred at the same time that the BoK and GTCM were developed. From perspectives outlined in these documents, MGIS programs are positioning themselves to be harbingers of professional education in geography where the focus is on a mutual respect for academic and business skills, but with an emphasis on the placement of graduates in BGN.

Results

In this section we first present an overview of who offers MGIS degrees and their cost, followed by an examination of enrollment numbers and number of degrees granted, and a discussion of the student body make-up. We then investigate the composition of faculty and models of delivery. Next, we look at the degree of integration that a program has with its home unit or department on campus. Finally, we look at what it means to be a professional program and the common elements of professional education.

Table 1 identifies the MGIS programs in the United States. Programs are dispersed across the contiguous U.S. and found in major metropolitan areas and smaller college towns. As we will discuss, location has implications for the mode of delivery and the student body a program attracts. Five universities have more than one MGIS program. At the University of Denver and the University of Arizona there are both online and in-person MGIS programs. At Clark University there is a fifth year MGIS and a MGIS in Development and Environment.[4] At George Mason University there is a Master's in Geographic and Cartographic Sciences and a Master's in Geoinformatics and Geospatial Intelligence. Of the programs included in the thirteen interviews, only one existed in the 1990s. Further, of the forty-six different programs, four came into existence in 2013-2014: John Hopkins University (2013); Philadelphia

University (2013); California State University Long Beach (2013); and, the University of Arizona (online, 2014). Only 37 percent (17/46) of MGIS programs were based in a doctoral-granting department, which points back to the emphasis MGIS programs have on training graduates for placement outside of academy. Data from all forty-six programs show the average cost to be $29,082, with the most expensive exceeding $58,000. These cost estimates were based on current out-of-state tuition rates and program fees published on websites, information that is not always easy to locate or calculate.

Program enrollment varied between five and 180 (n=13). The definition for enrollment reflected total students in MGIS programs at the time of our research (2013). Two large outliers (103, 180) skew the average and median enrollment numbers, which were 44 and 30 students, respectively. Removing the outliers reveals an average of 28 and a median of 25.5. A secondary source for comparing student body size comes from the National Center for Education Statistics. In 2010, fifty percent of the top twenty Master's in Geography degree granting departments also had MGIS programs. If we take a closer look at the most productive joint Master's degree-granting university, Arizona State University (ASU), then we see a clearer relationship between the geography degree program and the MGIS. In 2010, 84 percent (32/38) of the Master's degrees in geography granted by ASU came from its MGIS program.

Differences in the size and make-up of the student body reflect several interrelated factors, among them institutional location, delivery method (online or in-person), age of program, institutional polices, and curricular orientations. The two largest programs in terms of enrollment are offered online and are located outside of major metropolitan areas. However, in terms of degrees conferred, in-person programs tend to deliver more degrees per year than online degree programs. This is due in large part to the fact that students in online programs are

often working full time and so need more time to complete their degrees. Major metropolitan markets like Los Angeles and Washington D.C. have fostered multiple MGIS programs, though others like New York City and Chicago have not. In other regional markets an institutional commitment to offering start up resources to make MGIS programs viable have played a key role. In some cases, university administrators initiated MGIS degrees as a means to expand graduate education, while in others these degree programs were the result of specific faculty responding to a perceived market need for highly trained graduates. Within universities, where the MGIS program is located administratively (e.g. in a college of liberal arts, college of science, or outreach college), as opposed to where it is located within the academic unit granting the degree (e.g. a geography department), has affected the availability of resources for student recruitment, support, and fees. Across these differences, however, there is a general pattern of creativity in the form and development of programs.

The composition of MGIS faculty varies greatly among programs. The average size of home units was sixteen regular faculty members, but ranged from one to forty-seven. The average number of teachers in MSGIS programs was ten, with five coming from the regular faculty and three-and-a-half being external adjunct faculty. In one program external professional GIS adjuncts made up 80 percent of the instructors. The credentials and time commitments of the external faculty also vary considerably across programs. In one program, the preference was to only hire faculty that held a doctorate and did not work in industry; these faculty hires were appointed to full-time yearlong contracts. At another program the director argued, "To teach in this program, I really think a person should have professional experience" (Interview #8). Often, external professional GIS adjuncts are used to teach highly technical

components such as programing, web GIS, remote sensing, database management, or project management.

Differences among programs are also reflected in their models of delivery and the length of time it takes to complete a degree. 30 percent (14/46) of MGIS programs can be completed in one year. Also, 30 percent (15/46) can be completed online. MGIS programs commonly involve only required courses. In online MGIS programs, most students combine their studies with full-time employment. Online curricula are often organized in individual modules that are offered in shorter time blocks and that can be completed one at a time. Some online programs offer rolling admissions and opportunities for students to take breaks between courses because of exigencies of their work or personal issues. Five online programs have a short residential requirement. Three in-person programs employ a cohort approach where a group of students work their way through the degree at the same time. Cohort models are also used in some online programs. The benefit of the cohort model is that it creates an integrated community of learners and provides an efficient and flexible college education that promotes deeper, more lasting, and more transferable learning. This deeper learning is reinforced through the sense of community that is developed by a high frequency of interaction between students and faculty, which in turn reinforces a socially cohesive and a professional environment that broadens learning goals.

One way to differentiate among the programs is to consider their degree of integration with respect to the department within which they are situated. Integrated programs tend to share curriculum with their home unit and may require students to take similar courses as the non-MGIS graduate students in the unit, such as Geographic Thought. Programs that are less well integrated have their own courses and may also differ from their home unit through course

format and delivery, management and faculty, and funding sources. Students in a non-integrated program may be cut off from other graduate students in the unit by being online, in night classes, or separated by curriculum. Because the MGIS program is sometimes the dominant graduate program in a unit and because online programs cater to a new type of student, how we define a traditional student may be changing. Further, the issues faced by MGIS programs point toward management issues that are more reflective of small businesses than of academic units. As one program director remarked, "I think that one of our biggest challenges is that our institutions, and ours is not unique in this respect, are not yet internally prepared to deal with non-traditional students, graduate faculty issues, and how do you advise all these people" (Interview #2). Many programs are financially self-sufficient and managed separately from their home unit, but support their home unit by generating revenue. Non-integrated programs frequently had some social issues with how often MGIS students, faculty, and staff interact or with how the MGIS program is perceived by the home unit.

Many of the directors that we interviewed referred to their programs as professional. This relates to the need for education to have current academic rigor and also be geared toward students who are seeking careers in business, governmental, or non-profit organizations. In MGIS programs professional pedagogy can also be seen in an emphasis on the master's project over the master's thesis. 78 percent of the forty six MGIS programs had the option for students to do a master's project, while only 20 percent (9/46) required students to write a master's thesis. Further, only 59 percent (27/46) of MGIS program required a Graduate Records Exam (GRE) in their application process. Professional pedagogy emphasizes the DOLETA GTCM (referred to previously) as a foundation to the program's teaching philosophy. Here interpersonal skills, integrity, professionalism, initiative, dependability, and lifelong learning

provide the foundation of the pyramid; moving up in the pyramid, professional education is achieved through an emphasis on workplace competencies.

Common elements of professional education in MGIS programs include project management, presentation skills, writing skills, group work, ethics, internships, networking and conference attendance, resume writing, and the creation of personal websites. A key component of professional education is the incorporation of project management skills, often not as a distinct course, but as a reoccurring theme in every class. This may be partly in recognition that many of the students are already employed in industry or governmental agencies or are aiming to advance their careers to become managers in such settings. At one university management skills and training is so important it is reflected in the name of the program: Master of Science in GIS Management. The program directors that we interviewed regularly spoke of the importance of developing skills in workflow organization, teamwork, and interpersonal communication. As one said, "If you had the technical capability to do the job, that's the last issue on the list. It's like, do you know and like the people? Can they work with you? Can you explain your position? Project management is where you handle the workflow…what other people do…maybe there are some improvements that can be done" (Interview #8). Another reported, "I am teaching a project management class. So it's not about banging on a keyboard and doing GIS data management or analysis. It's about how you organize a project" (Interview #7). Yet another interviewee indicated that rather than offering a separate course, project management skills are "taught in every class and … several of us have group projects as part of our classes" (Interview #9).

Developing presentation skills is a key core competency in professional education. In one residential program, the first assignment for students is to prepare a PowerPoint

presentation that introduces themselves to their peers: “We drill in how to say it…how to trim it down, how to communicate clearly” (Interview #3). The program director goes on to comment that students are reminded that they are “not talking to the wall” (Interview #3). In many of the residential programs, students were required to present their capstone project, master’s project, or master’s thesis in public forums or classroom settings. All programs had an emphasis on writing. One program even had a staff editor to review and coach the students’ writing of the Master’s Project, while another had a specific focus on proposal writing.

Other frequently addressed professional activities for students included networking and internships. Many programs encouraged students to attend professional conferences, with the ESRI International Users Conference being the most frequently cited. Some programs created their own professional networking events including alumni reunions, annual program receptions, student career fairs, and ESRI Developer Meetups. Internships and applied projects were common across all programs and were individual or group efforts. Students enrolled in programs in larger metropolitan areas appear to have many choices when it comes to internships. As one director noted, “We have the risk of having too many intern sponsors and not enough students to fill the jobs” (Interview #7). Another reported that with multiple internship offerings available, the challenge is which ones students will choose. Internships for international students undertaken for course credit can offer a legal way for these students to earn money while not violating their visas. Some online programs require or promote cooperative projects with BGNs that are in the student’s own region. A student’s experience in these programs is such that the opportunities are highly valued by organizations and allow students to apply skills learned while building their resumes for postgraduate employment.

Professional ethics are addressed in several ways in MGIS programs. In one online program, students were required to take either a workshop or a four-credit course in GIS ethics. A few programs included discussions of ethical issues through the use of case studies provided by the GIS Professional Ethics Project that was designed to help "professional programs prepare current and future practitioners to recognize ethical problems and to act with integrity" (DiBiase et al. 2009, 1).[4] Finally, one program director commented that ethics were especially important when dealing with uncertainty and modeling:

> It's about being transparent in simplifying the assumptions you make. There are all sorts of dangers when you create a model and you don't expose to people why it doesn't work as well, or why it is an imperfect model for reality or why if you use this to make decisions, it could be wrong. It's the ethics that I think is important … human uncertainty is fascinating, but model uncertainty is dangerous (Interview #8).

Conclusion

The purpose of this study was to document a new trend in geography graduate education. The MGIS programs reviewed here highlight the importance of professional education and the skills needed for students to find employment in BGN. This research contributes knowledge to those seeking to establish a MGIS program, administrators needing to understand the diversity of MGIS programs, students who want to better understand their choice in graduate education, and geography departments seeking to implement professional education practices in their curriculum. MGIS programs challenge geography to think differently about the future of graduate education.

Professional education taught in MGIS programs focuses on training students for work in BGN. Professional education skill development is emphasized not only in the classroom, but also more importantly outside of the classroom in the form of internships, networking, conferences, and other professional development related activities. Professional education is a pedagogic philosophy that focuses on measuring academic program success one gainfully employed graduate at a time. It is the belief that in order to educate students for the fast growth STEM field of geospatial technologies, one must not only measure learning outcomes, but must equally emphasize soft skills that allow one to find a job and advance in the information economy. Soft skills include networking, resume writing, interviewing, internships, time management, writing and public presentations, leadership, working in groups, and project management. Professional education requires that the academy reconfigure program offerings to meet the demands of BGN as well as the changing needs of students. This means we will need to start seeing degrees that are obtainable in shorter periods of time or conversely, more flexible offerings for students who are already employed. It also means more diversified yet integrated options that provide skill-based training on specific topics of increasing professional relevance and/or aids in career advancement. Moreover, professional education implies a structured pedagogic response to differential learning where students may come in with completely different skill sets but all are equally challenged to improve their abilities and obtain their goals. Innovation and entrepreneurship require community-based learning environments and BGN outreach by MGIS programs as they must engage with the community that is hiring students. The MGIS program must lead this engagement by offering applied research, innovation, science, and technology support that cannot be found outside the university. But an emphasis on innovation and entrepreneurship does not just look outward to BGN; it must also

look inward in order to leverage university resources that facilitate its philosophical mission and to reconfigure normative pedagogic structures. Some may feel that MGIS programs are a part of the neoliberalization of academy, degree mills that focus on the production of labor for industry. This type of criticism points toward larger changes occurring at universities where academic labor must be measurable and every increasing. As MGIS programs incorporate professional education, are increasing in number, and graduates are looking toward BGN for jobs, it is easy to see how these programs could be aligned with a neoliberal critic. However, MGIS programs are also the harbinger of a new style of learning that fully embraces cutting edge theories, science, and technologies, all while blending them with professional education and new formations of educational delivery.

Notes

1. http://www.doleta.gov/Brg/Indprof/geospatial_profile.cfm (last accessed 16 February 2014).

2. http://www.ice.gov/doclib/sevis/pdf/stem-list.pdf (last accessed 16 February 2014).

3. A fifth year Master's degree is offered to bachelor's students from the home unit. These degrees can be completed in one year.

4. www.gisprofessionalethics.org (last accessed 16 February 2014).

References

Anderson, N. 2013. *Master's degree programs surge at nation's colleges and universities* 25 May. http://www.washingtonpost.com/local/education/masters-degree-programs-surge-at-nations-colleges-and-universities/2013/05/25/938462fa-b726-11e2-92f3-f291801936b8_story.html (last accessed 16 February 2014).

Baker, T., and Bednarz, S. 2003. Lessons learned from reviewing research in GIS education. *Journal of Geography* 102 (6): 231-233.

Baker, T. 2005. Internet-based GIS mapping in support k-12 education. *The Professional Geographer* 57 (1): 44-50.

Burrough, P.A. 1986. *Principles of geographic information systems for land resource assessment*. Oxford: Clarendon Press.

Carrivick, J. 2011. Exploring the value of professional body accreditation for masters programmes. *Journal of Geography in Higher Education* 35 (4): 479–497.

DiBiase, D., C. Goranson, F. Harvey, and D. Wright. 2009. *The GIS professional ethics project: practical ethics education for GIS pros*. https://www.e-education.psu.edu/sites/default/files/ethics/DiBiase_et_al_GIS_Pro_Ethics_ICC2009.pdf (last accessed 16 February 2014).

DiBiase, D., T. Corbin, T. Fox, J. Francica, K. Green, J. Jackson, G. Jeffress, B. Jones, J. Mennis, K. Schuckman, C. Smith, and J. Van Sickle. 2010. The new geospatial technology competency model: Bringing workforce needs into focus. *Journal of the Urban and Regional Information Systems Association* 22 (2): 55-72.

DiBiase, D., M. DeMers, A. Johnson, K. Kemp, A. Luck, B. Plewe, and E. Wentz. 2007. Introducing the first edition of geographic information science and technology body of knowledge. *Cartography and Geographic Information Science* 34 (2): 113-120.

DiBiase, D., M. DeMers, A. Johnson, K. Kemp, A. Luck, B. Plewe, and E. Wentz. 2006. *Geographic information science and technology body of knowledge*. Washington D.C.: Association of American Geographers.

DiBiase, D. 2003. On accreditation and the peer review of geographic information science education. *Journal of the Urban and Regional Information Systems Association* 15 (1): 7-14.

DOLETA. 2010. *Geospatial technology competency model*. Education and Training Administration, United States Department of Labor, Washington DC. www.careeronestop.org/competencymodel/ (last accessed 16 February 2014).

Ennis, M. 2008. *Competency models: a review of the literature and the role of the employment and training administration*. Pilots and Demonstration Team Division of Research and Evaluation Office of Policy Development and Research Employment and Training Administration U. S. Department of Labor 29 January 2008. https://www.careeronestop.org/competencymodel/info_documents/OPDRLiteratureReview.pdf (last accessed 16 February 2014).

Foote, K., D. Unwin, N. Tate, and D. DiBiase. 2012. GIS&T in higher education: challenges for educators, opportunities for education. In *Teaching geographic information science and technology in higher education*. ed. David Unwin, Kenneth Foote, Nicholas Tate, David DiBiase, 3-15. New York: Wiley-Blackwell.

Goodchild, M. 1985. Geographic information systems in undergraduate geography: A contemporary dilemma. *The Operational Geographer* 8: 34- 38.

Kawabata, M., R. Bahadur, T. Oguchi, and M. Tsou. 2010. Multidisciplinary cooperation in GIS education: a case study of US colleges and universities. *Journal of Geography in Higher Education* 34 (4): 493-509.

Kemp, K., M. Goodchild, and R. Dodson. 1992. Teaching GIS in geography. *The Professional Geographer* 44 (2): 181-191.

Kemp, K., and F. Goodchild. 1991. Developing a curriculum in geographic information systems: the national center for geographic information and analysis core curriculum project. *Journal of Geography in Higher Education* 15 (2): 123-135.

Kemp, K., and F. Goodchild. 1992. Evaluating a major innovation in higher education: the NCGIA core curriculum in GIS. *Journal of Geography in Higher Education* 6 (1): 21-35.

Kerski, J., A. Demirci, and A. Milson. 2013. The global landscape of GIS in secondary education. *Journal of Geography* 112 (6): 232-247.

Lee, J., and R. Bednarz. 2009. Effect of GIS learning on spatial thinking. *Journal of Geography in Higher Education* 33 (2): 183-198.

Lloyd, W. 2001. Integrating GIS into the undergraduate learning environment. *Journal of Geography* 100 (5): 158-163.

McMaster, S., and R. McMaster. 2012. The university of Minnesota master of geographic information science (MGIS) program: a decade of experience in professional education. In *Teaching geographic information science and technology in higher education*. ed.

David Unwin, Kenneth Foote, Nicholas Tate, and David DiBiase. 167-183. New York: Wiley-Blackwell.

Meyer, J., J. Butterick, M. Olkin, and G .Zack. 1999. GIS in the K-12 curriculum: a cautionary note. *The Professional Geographer* 51 (4): 571-578.

Monk, J., K. Foote, and B. Schlemper. 2012. Graduate education in U.S. geography: students' career aspirations and faculty perspectives. *Annals of the Association of American Geographers* 102 (6): 1432–1449.

Quality Assurance Agency for Higher Education. 2013. *Facets of mastersness: a framework for master's level study*. http://www.enhancementthemes.ac.uk/sheec/learning-from-international-practice/taught-postgraduate-student-experience/facets-of-mastersness (last accessed 16 February 2014).

Schulze, U., D. Kanwischer, and C. Reudenbach. 2013. Essential competences for GIS learning in higher education: a synthesis of international curricular documents in the GIS&T domain. *Journal of Geography in Higher Education* 37 (2): 257-275.

Sinton, D. 2009. Roles of GIS within higher education. *Journal of Geography in Higher Education* 33 (supplemental 1): s7-s16.

Solem, M., I. Cheung, and B., Schlemper. 2008. Skills in professional geography: an assessment of workforce needs and expectations. *The Professional Geographer* 60 (3): 356-373.

Solem, M., K. Foote, and J. Monk. 2013. *Practicing geography: careers for enhancing society and the environment.* Upper Saddle River, New Jersey: Prentice Hall.

Songer, L. 2010. Using web-based GIS in introductory human geography. *Journal of Geography in Higher Education* 34 (3): 401-417.

Tate, N., and D. Unwin. 2009. Teaching GIS&T. *Journal of Geography in Higher Education* 33 (supplemental 1): s1-s6.

Unwin, D., K. Foote, N. Tate, and D. DiBiase (eds). 2012. *Teaching geographic information science and technology in higher education*. New York: Wiley-Blackwell.

USGIF. 2013. *Collegiate geospatial intelligence certificate accreditation guidelines – 2013*. United States Geospatial Intelligence Foundation. 2325 Dulles Corner Boulevard, Suite 450. Herndon VA 20171. http://usgif.org/system/uploads/2745/original/USGIF_Accreditation_Guidelines_2013.pdf (last accessed 16 February 2014).

Warring, S. 2011. An analysis of learning levels within and between a degree and a diploma: New Zealand case study. *Quality Assurance in Education* 19 (4): 441 – 450.

Wikle, T. 1998. Continuing education and competency programmes in GIS. *International Journal of Geographical Information Science* 12 (5): 491-507.

Tables

Table 1: Masters in GIS programs in the United States

UNIVERSITY NAME	STATE	DEGREE NAME
University of Alabama	Alabama	MS Geography
University of North Alabama	Alabama	MS Geospatial Science
Arizona State University	Arizona	MAS Geographic Information Systems
Northern Arizona University	Arizona	MS Applied Geospatial Sciences
University of Arizona	Arizona	MS Geographic Information Systems Technology (Residential)
University of Arizona	Arizona	MS Geographic Information Systems Technology (Online)
University of Central Arkansas	Arkansas	Master of GIS Degree
California State University Long Beach	California	MS Geographic Information Science
California State University, Northridge	California	MA Geographic Information Science
San Diego State University	California	MS Geographic Information Science
San Francisco State University	California	MS Geographic Information Science
University of Redlands	California	MS Geographic Information Systems
University of Southern California	California	MS Geographic Information Science and Technology

American Sentinel University (Denver)	Colorado	Master of Geospatial Information Systems
University of Denver	Colorado	MS Geographic Information Sciences (Residential)
University of Denver	Colorado	MS Geographic Information Sciences (Online)
Florida State University	Florida	Applied MS Geographic Information Systems
Georgia State University	Georgia	MS Degree in Geosciences
Southern Illinois University, Carbondale	Illinois	MS Geography and Environmental Resources (GIS concentration)
Ball State University	Indiana	MS Applied Geographic Information System
University of Maryland, Baltimore County	Maryland	Masters in Professional Studies: Geographic Information Systems
Salisbury University	Maryland	MS in GIS Management
University of Maryland, College Park	Maryland	M. Professional Studies in Geospatial Information Sciences
Clark University	Massachusetts	MS Geographic Information for Development and Environment
Clark University	Massachusetts	M.A. Program in Geographic Information Science
Northeastern University	Massachusetts	MS of Professional Studies in Geographic Information Technology
Salem State University	Massachusetts	MS Geo-Information Sciences
Central Michigan University	Michigan	MS Geographic Information Sciences

Eastern Michigan University	Michigan	MS Geographic Information Systems
Michigan State University	Michigan	MS Geographic Information Systems
Saint Mary's University	Minnesota	MS GIS Winona Program
Saint Mary's University	Minnesota	MS GIS Minneapolis Program
University of Minnesota, Twin Cities	Minnesota	Master of Geographic Information Science
Delta State University	Mississippi	Master of Applied Science in Geospatial Information Technologies
Missouri State University	Missouri	MS Geospatial Sciences in Geography and Geology
Northwest Missouri State University	Missouri	MS Geographic Information Science
University of Montana	Montana	MS Geography with option in Cartography and GIS
North Carolina State University	North Carolina	Masters of Geospatial Information Science and Technology
Pennsylvania State University	Pennsylvania	MS Geographic Information Science and Technology
Philadelphia University	Pennsylvania	MS Geodesign
Sam Houston State University	Texas	MS Applied Geographic Information Systems
University of Texas at Dallas	Texas	MS Geospatial Information Sciences
George Mason University	Virginia	MS Geographic and Cartographic Sciences
George Mason University	Virginia	MS Geoinformatics and Geospatial Intelligence

John Hopkins University	Virginia	MS in Geographic Information Systems
University of Washington	Washington	Professional Master's Program in Geographic Information Systems