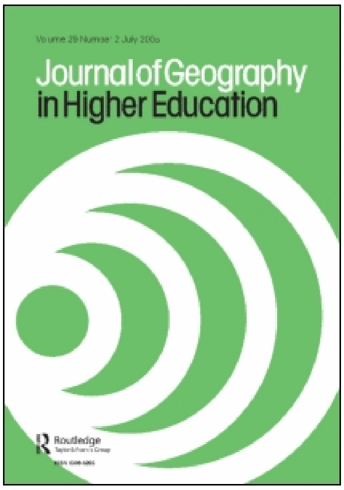

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Multidisciplinary Cooperation in GIS Education: A Case Study of US Colleges and Universities

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ABSTRACT *This paper examines the degree of multidisplinary cooperation for Geographic Information Science (GIS) education programs that award GIS-related degrees or certificates at US colleges and universities. We classified departments and courses into ten major disciplines using Dewey Decimal Classification. In the 2007–2008 academic year, approximately 40 per cent of GIS education programs related to multiple disciplines and nearly 20 per cent were involved with more than three disciplines. Geography was the major provider of GIS education programs, but the ratio between geography-related discipline and other disciplines combined was approximately 1:3. Fostering multidisciplinary GIS education programs should strengthen geography in general as well as GIS education.*

KEY WORDS: GIS education programs, multidisciplinary cooperation, geography, computer science, US colleges and universities

Introduction

Geographic Information Science (GIS) is a highly multidisciplinary research field that has become an important component of higher education. Recent articles in *Nature* point out that demand for GIS professionals is burgeoning because geospatial technologies are essential for many scientific research activities and observation methods (Gewin, 2004; Butler, 2006). In Japan, the Basic Plan of Promoting Geospatial Information Use, approved by the Cabinet in 2008, advocates that human resources for GIS are essential toward a 'Geospatially Enabled Society' (Cabinet Secretariat, 2008). Such growing demand for a GIS workforce is driven by the exploding use of geospatial technologies, including global positioning services, location-based services, remote sensing, spatial statistics and web-based mapping services.

Compared to the dramatically increased volume of GIS applications, the number of GIS-oriented education programs in universities is still limited in many countries.

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Possible explanations include the scarcity of funding GIS, difficulty of managing and supporting GIS campus-wide and the insufficiency of human resources for GIS education. Another possible explanation is the isolation of traditional disciplines that might impede multidisciplinary cooperation. Studies suggest that academic cooperation among multiple disciplines is an effective strategy for developing GIS education programs (DiBiase *et al.*, 2006; Ekstrom, 2006; Okabe, 2006; Murayama, 2008). In particular, cooperation between geography-related and computer science/information-related disciplines is an important element in comprehensive GIS education (DiBiase *et al.*, 2006; Okabe, 2006). Two recent developments of GIS model curricula exemplify the necessity of multidisciplinary cooperation and cooperation between geography-related and computer science/information-related disciplines in particular. One is the US model curricula, *Geographic Information Science and Technology (GIS&T): Body of Knowledge*, which was developed by a large number of professionals who were coordinated by the Education Committee of the University Consortium for Geographic Information Science (UCGIS) (DiBiase *et al.*, 2006). Another is the GIS core curricula of Japan, which was initially developed by a working group from the Geographic Information Systems Association of Japan (Okabe *et al.*, 2004; Kawabata *et al.*, 2005) and further developed by a government-funded research project titled 'Development of Curricula for Geographic Information Science and a Sustainably Collaborative Web Library System for Serving the Materials of the Curricula'. The project was conducted over three consecutive fiscal years 2005–2008 (http://curricula.csis.u-tokyo.ac.jp/index.php). In this project, more than 40 researchers from various disciplines in Japan collaborated to formulate the GIS core curricula (Okabe, 2008), featuring a good example of multidisciplinary cooperation. A unique feature of the GIS core curricula of Japan is cooperation between geography and computer science/information technology; the curricula integrated a GIS core curriculum developed by a geography-related group (Oguchi *et al.*, 2008) and one developed by a computer science/information technology-related group (Arikawa *et al.*, 2008).

Another example of multidisciplinary cooperation in Japan is the government-funded research project titled 'Establishment of Education Methods of Geographic Information Science: How to Teach GIS at Universities Effectively', which was carried out over four consecutive fiscal years 2005–2009 (http://gis.sk.tsukuba.ac.jp/indexold.htm). In this project, scientists, engineers and educators from various disciplines have collaborated to develop effective methods of GIS education (Murayama, 2007). However, in current GIS education provided at universities in many countries including Japan, successful cooperation among different disciplines remains hardly implemented.

Conversely, a large number of United States' (US) colleges and universities offer academic programs that award GIS-related degrees or certificates (hereafter referred to as 'GIS education programs'). Studies indicate that US GIS education programs are often created through multidisciplinary arrangements (Wikle, 1998; Wikle & Finchum, 2003; Kawabata *et al.*, 2006). However, the degree of multidisciplinary cooperation in GIS education programs is not well understood; therefore, in this paper, we examined recent GIS education programs at US colleges and universities with attention paid to the degree of multidisciplinary cooperation, particularly that between geography-related and computer science/information-related disciplines. The results of this study can help us understand GIS education in US higher education institutions and shed light on the need for multidisciplinary cooperation not only for the US but also for many other countries.

Methods

This study analyzed 163 GIS education programs at US colleges and universities in the 2007–2008 academic year. For selecting the GIS education programs, we used the list of *Colleges and Universities with Existing GIS Certificate Programs* on the Urban and Regional Information System Association (URISA) website (http://urisa.org/career/colleges). URISA is one of the most recognized GIS professional and educational associations and is a key founder of the GIS certification Institute (http://www.gisci.org). The URISA's list includes GIS education programs that award GIS-related degrees (degree programs) as well as certificates (certificate programs). Information on the list was collected from individuals who asked that their institution be included. Although the list is not complete, it contains a large number (176) of GIS education programs in the US as of December 2007. Therefore, the data in the list permit us to examine the general trend of GIS education in the US. We investigated each of these 176 GIS education programs and selected those programs that offered online curriculum information. As a result, we examined 163 GIS education programs in 108 US colleges and universities for the 2007–2008 academic year. Note that some bias is inevitable by using the online information only. However, given that the number of the GIS education programs examined is relatively large and given that most curriculum information is available online, our analysis can capture the general state of multidisciplinary cooperation in GIS education.

Next, online information about curriculum, departments and courses of these GIS education programs were compiled into a database. The database was used to examine three aspects of the GIS education programs: (1) the number of degree and certificate programs; (2) composition of disciplines and multidisciplinary cooperation and (3) cooperation between geography-related and computer science/information-related disciplines. In our analysis, academic entities such as departments, schools and centers are all referred to as *departments*, and both Geographic Information System(s) and GIS are referred to as *GIS*. In this study, *multidisciplinary cooperation* indicates that mutiple departments from different disciplines cooperate to provide courses comprising a GIS education program; hence a program with multidisciplinary cooperation includes at least two departments of different disciplines. The number of disciplines comprising each GIS education program is regarded as the degree of multidisciplinary cooperation. Note that cooperation in this study is at the administrative level and does not distinguish the details of cooperation, for example, between cooperation in designing curricula and that in developing course contents.

We used Dewey Decimal Classification (DDC) (OCLC, 2003) to classify disciplines, because the DDC system is the most widely used classification system in libraries globally, and libraries accommodate a broad range of disciplines. The first summary of DDC contains the following ten main 'classes':

- 000: Computer Science, Information & General Works (CSIG)
- 100: Philosophy & Psychology
- 200: Religion
- 300: Social Sciences
- 400: Language
- 500: Science
- 600: Technology
- 700: Arts & Recreation

- 800: Literature
- 900: History & Geography

In the DDC system, each of these main classes is divided into ten 'divisions', each of which is further divided into ten 'sections'. In this study, departments offering courses for the GIS education programs were classified into the ten major classes (disciplines) based on their names. When a department name indicated more than one discipline, the department was classified into a discipline using the following criteria. Departments with names that included 'computer' or 'information system(s)' were classified into the discipline of Computer Science, Information & General Works (CSIG); similarly, departments with names that included 'technology' or 'engineering' were classified into the Technology discipline, those whose with names that included 'geography' were classified into the History & Geography discipline, and those with names that were difficult to classify (including GIS) were classified into the *Others* category. GIS was classified into *Others* because classifying multidisciplinary GIS into a particular discipline was difficult. Each course in a GIS education program was classified into the discipline of the department that provided the course. Note that a GIS education program relates to multiple disciplines if two or more departments of different disciplines participate in the program.

Results

Number of Degree and Certificate Programs

The number and proportion of GIS education programs offering degrees or certificates for the 2007–2008 academic year are shown in Figure 1. Of the 163 GIS education programs under study, 45 (28 per cent) are degree programs: 18 offer graduate degrees, 11 offer bachelor's degrees and 16 offer associate degrees. The remaining 118 programs (72 per cent) are certificate programs, indicating that GIS certificate programs are much more popular than GIS degree programs.

Composition of Disciplines and Multidisciplinary Cooperation

Among the 163 GIS education programs examined, 159 offer courses with discipline information (i.e. information on associated departments is available), and the total number of the courses is 2565. The proportion of each discipline included in the 159 GIS education programs is shown in Figure 2. Note that a GIS education program can involve multiple disciplines (i.e. multiple departments with different disciplines provide courses comprising the program). The total of the proportions is 197 per cent, indicating that each GIS education program may be associated with two disciplines on average. (Note that the values of the proportions have been rounded off.) Among the ten major disciplines of the DDC, History & Geography is involved with more than half (52 per cent) of the GIS education programs. Thirty per cent of the GIS education programs are associated with Science, 28 per cent with Technology, 25 per cent with Social Sciences and 18 per cent with CSIG. Both Arts & Recreation and Language are included in 8 per cent of the GIS education programs. Literature is included in only 1 per cent. The ratio between History & Geography and other disciplines combined is approximately 1:3 (82:231). Since no GIS

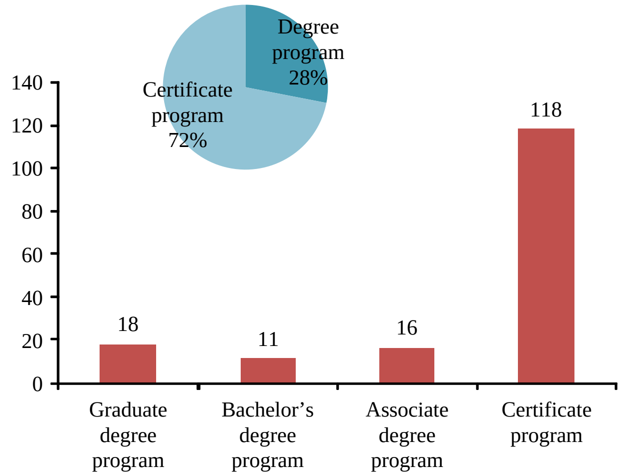
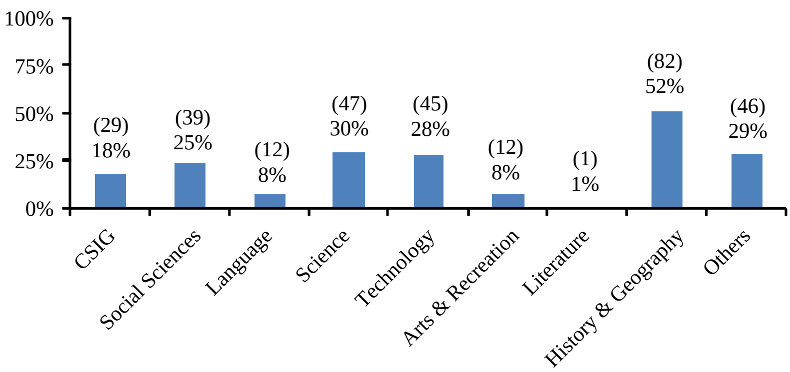


Figure 1. Number and proportion of GIS education programs offering degrees and certificates (2007–2008)

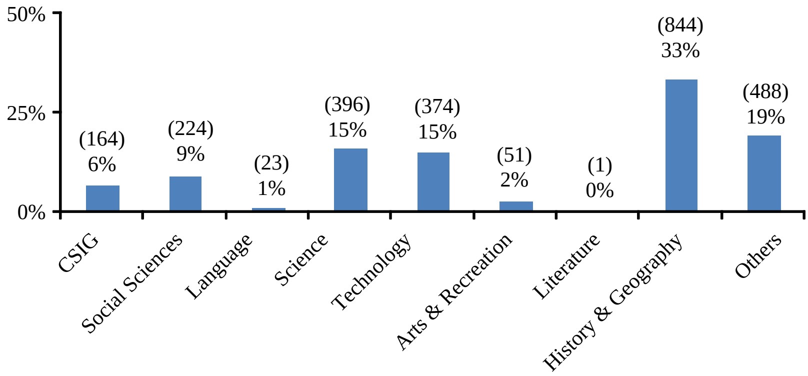
education program belongs to Philosophy & Psychology or to Religion, these two disciplines do not appear in the present and subsequent results.

Figure 3 shows the proportion of each discipline in the 2565 courses offered in the 159 GIS education programs. History & Geography still accounts for the largest proportion (33 per cent) in the total distribution. In fact, only three courses in two GIS education programs are related to history; therefore History & Geography can be considered primarily as geography. Science and Technology account for the second largest proportions (15 per cent each). Social Sciences and CSIG account for 9 and 6 per cent, respectively. The other three disciplines of Arts & Recreation, Language and Literature account for very small proportions (2 per cent or less).



CSIG: Computer Science, Information & General Works
Note: The numbers of GIS education programs are in parentheses. A GIS education program can include multiple disciplines.

Figure 2. Proportion of each discipline included in GIS education programs

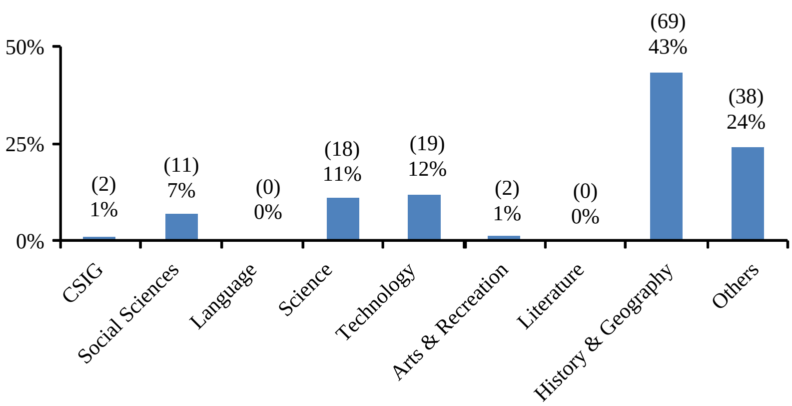


CSIG: Computer Science, Information & General Works
Note: The numbers of courses are in parentheses.

Figure 3. Proportion of each discipline in all courses of GIS education programs

Next, we examined the composition of a main discipline in the 159 GIS education programs (Figure 4). In this study, a main discipline is defined as the discipline that provides the largest number of courses in each GIS education program. If multiple disciplines in a program provide the same largest number of courses, the value of 1 divided by the number of main disciplines was added to the composition of each main discipline; for example, if a program has two main disciplines, 0.5 was added to each discipline. Again, History & Geography is the most common main discipline (43 per cent) in the GIS education programs. This proportion is considerably higher than that for the other disciplines. Science, Social Sciences and Technology account for approximately 10 per cent each. Arts & Recreation, CSIG and Literature are rarely main disciplines.

Figure 5 shows the number and proportion of the 159 GIS education programs by the number of disciplines comprising each program; in this study, the number of disciplines



CSIG: Computer Science, Information & General Works
Note: The numbers of GIS education programs are in parentheses.

Figure 4. Proportion of each main discipline in GIS education programs

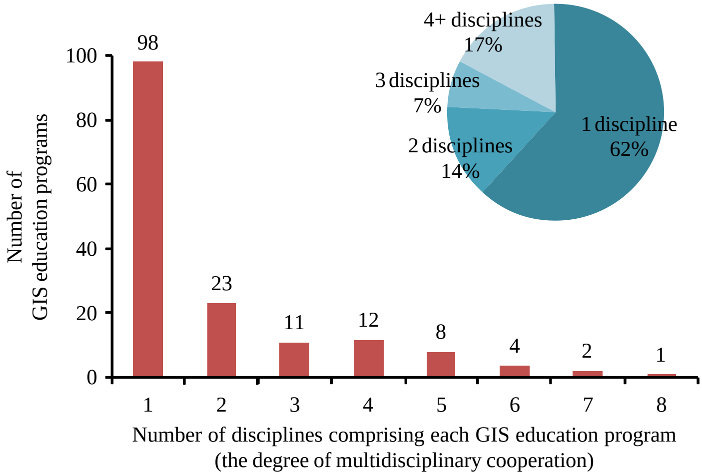


Figure 5. Number and proportion of GIS education programs by the degree of multidisciplinary cooperation

indicates the degree of multidisciplinary cooperation. The degree varies widely, from no cooperation (i.e. single-discipline programs) to cooperation among eight disciplines. Although the majority (62 per cent) of the GIS education programs are based on a single discipline, a noticeable proportion (38 per cent) is offered with cooperation between multiple disciplines, and 17 per cent of the GIS education programs are based on cooperation among four or more disciplines.

The proportion of GIS education programs by the degree of multidisciplinary cooperation varies considerably depending on whether the programs award degrees or certificates (Figure 6). The proportion of programs involving cooperation between multiple disciplines is relatively small for graduate degree and certificate programs (22 per cent and 32 per cent, respectively; note that the values of the proportions in Figure 6 have been rounded off), whereas it is relatively high for bachelor's degree and associate degree programs (73 and 81 per cent, respectively). These results suggest that multidisciplinary cooperation is relatively active in the bachelor's degree and associate degree programs compared to the graduate degree and certificate programs. In particular, the proportion of cooperation among four or more disciplines is markedly high (63 per cent) in the associate

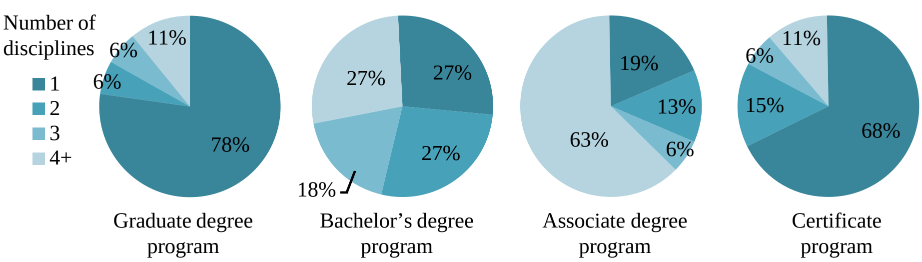


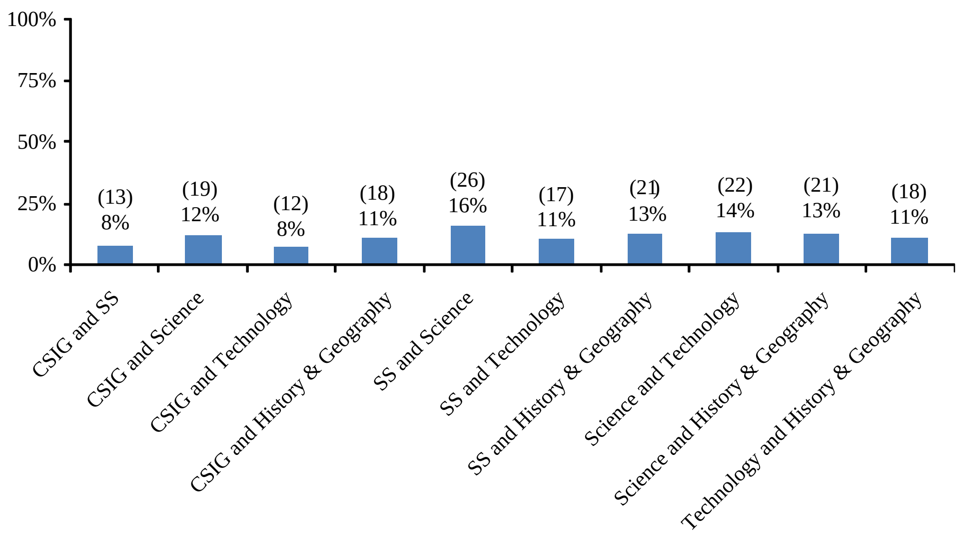
Figure 6. Proportions of GIS education programs by the degree of multidisciplinary cooperation depending on whether they are degree or certificate programs

degree programs, which may suggest that the need for multidisciplinary cooperation is high for community college education.

As shown in Figure 2, CSIG, History & Geography, Science, Social Sciences and Technology were the five most dominant disciplines in the GIS education programs. We therefore examined multidisciplinary cooperation among these disciplines for the 159 GIS education programs. Figure 7 shows the proportions of GIS education programs that involve cooperation between two of the five disciplines. Interestingly, all the proportions are approximately 10 per cent (range = 8–16 per cent). The highest proportion (16 per cent) was recorded for cooperation between Science and Social Sciences. The lowest proportion (8 per cent) was recorded for cooperation between CSIG and Social Sciences and between CSIG and Technology. Figure 8 further presents the proportions of GIS education programs that involve cooperation among three of the five disciplines. The proportions are approximately 8 per cent (range = 4–10 per cent). The highest proportion (10 per cent) was recorded for cooperation among Science, Social Sciences and Technology and among Science, Social Sciences and History & Geography. The lowest proportion (4 per cent) was recorded for cooperation among CSIG, Social Sciences and Technology and among CSIG, History & Geography and Technology.

Cooperation Between Geography-Related and Computer Science/Information-Related Disciplines

Finally, we present results for cooperation between the geography-related and computer science/information-related disciplines. Here, the geography-related discipline is defined



CSIG: Computer Science, Information & General Works
SS: Social Sciences
Note: The numbers of GIS eduction programs are in parentheses.

Figure 7. Proportions of GIS education programs that involve cooperation between two of five disciplines of CSIG, History & Geography, Science, Social Sciences and Technology

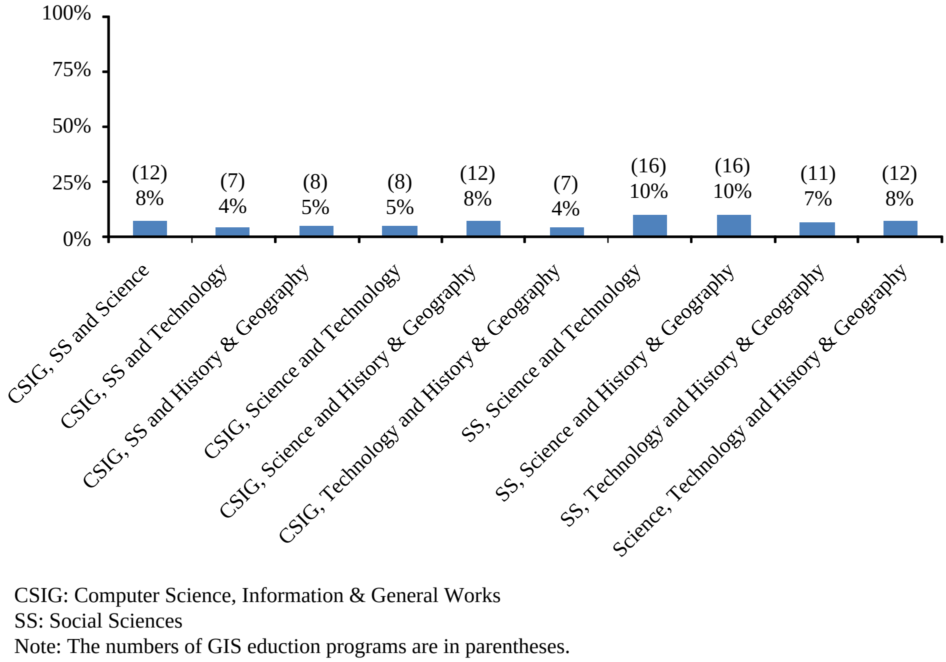


Figure 8. Proportions of GIS education programs that involve cooperation among three of five disciplines of CSIG, History & Geography, Science, Social Sciences and Technology

as the geography part of the DDC History & Geography discipline, that is, when a department name includes ‘geography’, the department and its courses are classified into the geography-related discipline. The computer science/information-related discipline is equivalent to the DDC CSIG discipline. Tables 1 and 2 show the department names and numbers of courses that belong to the two disciplines. Of the 2565 courses, the geography-related and computer science/information-related disciplines provide 841 and 163 courses, respectively. The number of courses from the geography-related discipline is considerably larger than that from the computer science/information-related discipline; however, the

Table 1. Departments and courses of geography-related discipline

Department name	Number of departments	Number of courses
Applied geography	1	7
Geography	58	550
Geography & Anthropology	2	15
Geography & Environmental Studies	1	8
Geography & Geology	4	35
Geography & Geosciences	1	5
Geography & Geospatial Science	3	45
Geography & Planning	8	113
Geography, Planning & Recreation	2	21
Geography & Regional Planning	3	42
Total	83	841

Table 2. Departments and courses of computer science/information-related discipline

Department name	Number of departments	Number of courses
Computer Aided Design	1	4
Communication, Information & Library Studies	1	2
Computer Information Science	3	9
Computer Information System(s)	5	27
Computer Information Technology	2	5
Computer Science	16	72
Computer Science & Engineering	1	7
Computer Science & Information Systems	2	21
Computer Science & Mathematics	1	2
Management Information Systems	1	2
Management Science & Information Systems	2	5
Mathematics & Computer Science	1	4
Multimedia	1	3
Total	37	163

computer science/information-related discipline still accounts for 6 per cent of the total number of courses.

Figure 9 exhibits the proportions of the GIS education programs offered by only the geography-related discipline, only the computer science/information-related discipline and both disciplines. Of the 159 GIS education programs, 28 per cent are based solely on the geography-related discipline, whereas no program is based solely on the computer science/information-related discipline. GIS education programs that include both the geography-related and computer science/information-related disciplines account for 11 per cent. This result indicates that while the computer science/information-related discipline hardly comprises GIS education programs as a single discipline, it is more likely to cooperate with the geography-related discipline to comprise a GIS education program.

Table 3 presents more detailed information about the 17 GIS education programs involving cooperation between the geography-related and computer science/information-related disciplines. Only 4 (24 per cent) of the 17 programs are based on cooperation only

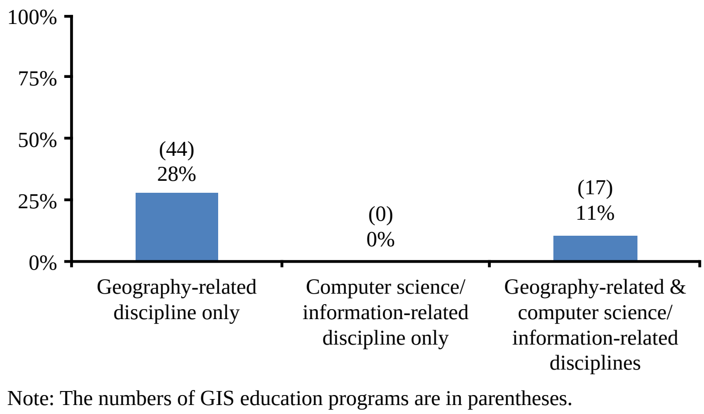


Figure 9. Proportion of GIS education programs offered only by the geography-related discipline, only by the computer science/information-related discipline and by both disciplines

Table 3 GIS education programs with cooperation between geography-related and computer science/information-related disciplines

University/College	Degree/Certificate	Geography-related department	Computer science/ information-related department	The other-discipline departments
Bismarck State College	Associate	Geography	Computer Information Science Computer Science	Economics English GIS Management Mathematics Political Science
Clackamas Community College	Associate	Geography	Computer Science	Drafting Math
Clackamas Community College	Certificate	Geography	Computer Science	Drafting Math
Columbus State Community College	Associate	Geography	Computer Information Technology	Communication Skill English Environmental Technology GIS Landscape Design/build Mathematics Social Science Surveying
Community College of Philadelphia	Associate	Geography	Computer Information System	Architecture Design & Construction English GIS Mathematics Social Science
Cosumnes River College	Certificate	Geography	Computer Science	Agriculture Anthropology Architecture Biological Sciences Business Fire Technology Geology Sociology
Bluegrass Community & Technical College	Certificate	Geography	Computer Information Technology	Architectural Technology Civil Engineering Technology Environmental Science Technology

(*Continues*)

Table 3. *Continued*

University/College	Degree/Certificate	Geography-related department	Computer science/ information-related department	The other-discipline departments
Mesa Community College	Certificate	Geography	Computer Information System Mathematics & Computer Science	n/a
Oklahoma State University	Certificate	Geography	Computer Science Management Science & Information Systems	Biosystem Engineering Civil & Environmental Engineering Plant & Soil Science Forestry General Technology Mathematics
Rowan University	Certificate	Geography & Anthropology	Computer Science Management & MIS	
Rutgers University	Certificate	Geography	Computer Science Management Science & Information Systems Communication, Information & Library Studies	Earth & Environmental Sciences Ecology Statistics Marine & Coastal Sciences Urban Planning & Policy Development
San Diego State University	Certificate	Geography	Computer Science	n/a
Temple College	Certificate	Geography	Computer Aided Design Computer Information Systems	n/a
Temple College	Associate	Geography	Computer Aided Design Computer Information Systems	English Environmental Science Geology Sociology
University of Minnesota	Masters	Geography	Computer Science & Engineering	Forest Resources
University of Texas at Dallas	PhD	Geography & Geospatial Science	Computer Science	Electrical Science Geoscience Economic, Political & Policy Management
University of Utah	Certificate	Geography	Computer Science	n/a

between the two disciplines, whereas the remaining programs (76 per cent) involve cooperation with some other disciplines in various subject disciplines, such as anthropology, civil engineering and economics.

A good example of cooperation between the geography-related and computer science/information-related disciplines is the GIS certificate program at San Diego State University. This program was developed through the joint efforts of the Department of Geography and the Department of Computer Science, and is administered by the two departments with one co-director from the Department of Geography and another co-director from the Department of Computer Science. The GIS certificate requires a total of 27 units including 12–15 units from the Department of Geography and 12–15 units from the Department of Computer Science listed in Table 4. The two courses in the Department of Computer Science, 'Component GIS architecture' and 'Spatial databases', are newly created for GIS education.

Discussion

We have examined 163 GIS education programs offered by US colleges and universities in the 2007–2008 academic year. Of the 163 programs, 45 award degrees whereas 118 award certificates, indicating that certificate programs were more popular than degree programs. About a decade ago, in the US, only 20 GIS certificate programs were found online and only a few GIS degree programs were provided (Wikle, 1998, 1999). The notable increase in GIS education programs over the past decade indicates a growing demand for academic programs that impart GIS skills and knowledge, and the increase for degree programs suggests the strong need of systematic and advanced GIS education.

As noted by Murphy (2007), GIS education programs are indeed becoming popular among students, which reflects rising interest in geospatial technology. Although GIS has been known to a relatively limited number of people until recently, geospatial tools and applications like Google Earth are now widespread among the general population. It is not surprising that an increasing number of students are drawn to learn the capability and

Table 4. Courses in GIS certificate program at San Diego State University

Department of Geography	Department of Computer Science
Geographic information science and spatial reasoning	Visual basic programming
Computerized map design	Introduction to computer programming (required)
Geographic information systems (required)	Intermediate computer programming (required)
Cartographic design	Unix and the C programming language
Internet mapping and distributed GIServices	Data structures
Geographic information systems applications	Programming languages
Quantitative methods in geographic research	Scientific database techniques
Remote sensing of the environment	Database theory and implementation
Intermediate remote sensing of the environment	Advanced programming languages
GIS-based decision support methods	Object-oriented programming and design
Advanced topics in GIScience	Component GIS architecture
	User interface environments
	Super computing for the sciences
	Advanced topics in geocomputation
	Spatial databases

potential of GIS. The growth of GIS education programs also reflects expanding employment opportunities and prospects for GIS professionals, as employment conditions and outlook certainly impact academic programs (Koutsopoulos, 2008). The market pressure on academic programs seems to be increasingly influential, since postgraduate certificate programs have grown rapidly (DiBiase, 2003; McEwen *et al.*, 2008) and vocationally oriented academic programs have increased in higher education in geography (McEwen *et al.*, 2008). These recent trends suggest that the demand for GIS education programs will continue to grow, and that colleges and universities are expected to augment GIS education programs.

In this study, we classified departments and courses comprising GIS education programs into the ten major DDC disciplines and examined multidisciplinary cooperation. In the 2007–2008 academic year approximately 40 per cent of GIS education programs were based on cooperation between multiple departments from different disciplines, and about 20 per cent involved cooperation among four or more departments from different disciplines. These proportions signify the multidisciplinary characteristics of GIS. In fact, the actual level of multidisciplinary cooperation is likely to be higher, since the *Others* category includes a mixture of disciplines that overlap with more than one of the ten disciplines of the DDC.

Among the ten major DDC disciplines, History & Geography led in the total number of courses and had the largest proportion as the main discipline in the GIS education programs. Since history accounted for an extremely small portion of History & Geography, the result suggests that geography plays a leading role in GIS education program. Indeed, Murphy (2007, p.133) observes that "in institutions with geography departments, it is quite common for that department to be the principal home of GIS and the principal purveyor of GIS courses". However, the ratio between geography-related discipline and other disciplines combined for the GIS education programs was 1:3. This ratio suggests that promoting multidisciplinary cooperation in GIS education should be a key task for geography-related departments. The promotion of multidisciplinary cooperation is also valuable to the discipline of geography. In his Past President's Address: 'Prospects for Geography as an Interdisciplinary Discipline' at the Association of American Geographers 2009 Annual Meeting, Thomas Baerwarld noted that since geography is inherently interdisciplinary, interdisciplinary collaboration is beneficial to geography (Baerwald, 2009).

It is now widely accepted that GIS has become an indispensable component in geographic education, but GIS still tends to be taught as a peripheral aspect of this education (Higgit, 2008). Stressing the central role of geoinformation in paradigm changes in European geography, Koutsopoulos (2008, p.8) states that "geographers will be in the information business (or no business at all)". Murphy (2007) notes that over the past 15 years the significance of geography in US higher education has been augmented, and the exploding interest in GIS is a reason for this rebounded significance. China has a similar experience. The number of geography programs in Chinese higher education has expanded considerably since 1999, mainly due to an increase in geography programs focusing on GIS as well as on urban–rural planning and resources management (Li *et al.*, 2007). GIS expands not only the breadth but also the depth of geography; for instance, the knowledge of GIS helps to deepen spatial thinking, which is an essential component in geography. Consequently, fostering GIS as a core component in geographic education should strengthen geography in general as well as GIS education.

Among the other nine major DDC disciplines, CSIG, Science, Social Sciences and Technology played comparatively significant roles, as they accounted for relatively high proportions in the total number of courses and were frequently included in the GIS education programs. Examining multidisciplinary cooperation among the above five disciplines, we found that all possible combinations of two or three of the five disciplines occurred with similar frequencies. Therefore, there is no common pattern of multidisciplinary cooperation in GIS education programs and various types of cooperation have been attempted. This result confirms the versatility and multidisciplinary characteristics of GIS.

While examining cooperation between the geography-related and computer science/information-related disciplines, we found that such cooperation was realized in only about one-tenth of the GIS education programs, even in the US. The close link between the two disciplines is increasingly regarded as an important aspect of GIS education, as demonstrated by the following two recent GIS model curricula. One is the GIS&T Body of Knowledge; its title and contents indicate the significance of an interrelationship between geography and information technology in GIS education. Another is the GIS core curricula of Japan, which integrated core curricula developed by a geography-related group and a computer science/information technology-related group. Effective use of such model curricula may promote cooperation between the geography-related and computer science/information-related disciplines.

Our study has also shown that although the computer science/information-related discipline was included in about 20 per cent of the GIS education programs, no GIS education program was based solely on the computer science/information-related discipline, and it was the main discipline of only 1 per cent of the GIS education programs examined. Given that geospatial technology is evolving into a main stream technology (Gewin, 2004; Butler, 2006), this situation may change, resulting in computer science/information-related disciplines being more likely to become actively involved in GIS education. Moreover, given that geospatial technology requires a deep understanding of geographic concepts (Gewin, 2004), the computer science/information-related departments may collaborate more actively with geography-related departments. A good example is the case of San Diego State University, where the Department of Computer Science cooperates willingly with the Department of Geography for developing GIS education. Ming-Hsiang Tsou, a faculty member in the Department of Geography there, notes that successful multidisciplinary cooperation relies on mutual trust among key faculty members in both departments, and that for cultivating the mutual trust, personal engagements (such as brown bag meetings, proposal development activities and office visits) are extremely important. He also points out that successful multidisciplinary cooperation does not create a dramatic change in teaching and management loads.

GIS education programs are considerably more advanced in the US than in many other countries including Japan, where GIS education involving cooperation between multiple departments of different disciplines is almost non-existent. To our knowledge, no official GIS education program exists at Japanese universities, although a large number of GIS-related courses are offered in various departments; Sasaki *et al.* (2008), for example, found that more than 200 GIS-related courses are offered in Japan's geography-related departments alone. The US case shown in this study suggests that promoting multidisciplinary cooperation is an effective method for developing GIS education programs. In fact, Wikle (1999) notes that the act of developing GIS education programs can enhance multidisciplinary cooperation. Developing academic programs for relatively new and multidisciplinary GIS often requires a number of years and a succession of compromises among faculty members (Wikle & Finchum, 2003). Nonetheless, multidisciplinary effort is a worthwhile endeavor. Experiences at some US higher education institutions demonstrate that multidisciplinary cooperation helps to augment the awareness of GIS on campus, increase funding opportunities and financial support for GIS education and cultivate human resources for GIS education (Cunningham & Steward, 2006; Ekstrom, 2006; Muller *et al.*, 2006). By cooperating among multiple disciplines, more faculty and students will understand the importance of GIS and adopt GIS in their activities. Multidisciplinary cooperation can also increase student enrollments and make students more competitive in job market; acquiring GIS knowledge as well as domain knowledge (such as biology, geography and environmental sciences) will make students more valuable and competitive.

Fostering GIS education is a pressing issue in many countries; therefore, it is necessary to examine and compare the cases of other countries such as those in Asia and Europe with the US case. Such future research will help to assess the characteristics and importance of multidisciplinary cooperation in GIS education from a global perspective. Further future research should examine the details of the multidisciplinary nature of GIS education programs using relevant information such as the GIS&T Body of Knowledge. Course requirements and contents of GIS education programs can be extremely diverse (Wikle, 1998, 1999; DiBiase, 2003; Kawabata *et al.*, 2006), making it difficult to select an appropriate GIS education program and evaluate the usefulness of an earned GIS-related degree or certificate. Sasaki *et al.* (2008) find mismatches between current GIS education in geography-related departments and the GIS core curriculum developed by the geography-related group in Japan. Extending such research will help to evaluate GIS education programs, draw effective guidelines for awarding GIS degrees or certificates and promote multidisciplinary cooperation for developing GIS education programs.

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