CURRICULUM DEVELOPMENT FOR A COMMUNITY COLLEGE, SKILLS-BASED GIS CERTIFICATE PROGRAM USING DACUM/SCID & THE UCGIS BODY OF KNOWLEDGE

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I INTRODUCTION

To update and improve the quality of its GIS Certificate program, San Diego Mesa College is using two complementary curriculum resources; DACUM/SCID and the UCGIS Body of Knowledge. DACUM/SCID is being used to both identify the skills required of its graduates and design the new skills-based program. The Body of Knowledge is providing the general GIS&T knowledge framework as well as detailed educational/learning objectives for the curriculum.

The DACUM (an acronym for "Developing A CUrriculuM") process for job/occupational analysis is in use worldwide. It has proven to be an effective method for quickly determining, at relatively low cost, the tasks that must be performed by persons employed in a given job or occupational area. At San Diego Mesa College this process was applied to the job of GIS Technician. It resulted in the generation of a comprehensive DACUM research chart which is a graphic profile of the important duties and tasks performed by workers in this position. This chart serves as a foundation for the curriculum development process known as SCID (Systematic Curriculum and Instructional Development). This process, designed specifically to implement DACUM results, is being used to generate curriculum for Mesa skills-based GIS Certificate Program.

The UCGIS Body of Knowledge, released in 2006, seeks to clarify and define the parameters of the field of Geographic Information Science & Technology (GIS&T) and help to standardize the curriculum for all geospatial programs in the country. With this in mind, it identifies ten general knowledge areas, 73 units, 329 topics, and over 1,600 formal educational or learning objectives. The Body of Knowledge is not in itself a curriculum, but instead is intended to be used as a resource or clearinghouse for geospatial curriculum developers.

The Body of Knowledge was developed out of a concern that many students enrolled in GIS certificate and degree programs are not being "properly prepared for the workplace". This has resulted from a general lack of educational standards and regulations within the industry and a lack of compatibility and consistency between programs. In addition, it is unclear which of the various knowledge and skills being taught in these programs are necessary or even useful to those seeking to become GIS professionals.

Most curriculum planning and development initiatives involve a "bottom-up" approach where a set of topics are organized into classes which comprise the curriculum. A common problem with this approach is that most often, the initial set of topics has never been critically evaluated in terms of what the students need to know to be successful in their field. In contrast, both DACUM and The Body of Knowledge were envisioned to be used for curriculum development in a "top-down" approach. Both begin with broad educational objectives which are then organized into topics and associated competencies. These competencies are then defined by specific learning objectives which in turn form the basis of the new curriculum.

With DACUM, the goal is to teach students only the knowledge and skills that are considered necessary for them to perform effectively on the job immediately upon graduation. The Body of Knowledge on the other hand, has a much broader and more comprehensive goal. It seeks to prepare students for careers in Geographic Information Science and Technology.

II. GIS CERTIFICATE PROGRAM AT SAN DIEGO MESA COLLEGE

According to ESRI's online database of Academic GIS Programs, there are currently one hundred and eighty seven GIS Certificate Programs within the United States. Of these, approximately 65 percent are at four-year universities and 35 percent are at two-year community colleges. While the length of these programs vary, most are more narrowly focused and require less time to complete than comparable degree programs at the same institution.

The GIS Certificate Program at San Diego Mesa College consists of four, 3-unit classes and an internship. There are no perquisites which means that students entering the program often have only a limited grasp of computers, math and other basic skills. Although the College has the option of increasing the length of this program and establishing prerequisites, this is not being pursued as it would likely have a detrimental effect on student enrollment. In addition, increasing the length of the program to more than 16 units would require changing the program from a Certificate of Completion to a Certificate of Achievement. This would have the added burden of requiring the state's Chancellor's Office to approve the program along with any modifications made to it. As a 16 unit, Certificate of Completion, the program can continue to operate with only district level approval. Consequently, modifications are currently being made only to the curriculum while maintaining the structure of the program intact.

With only 4 classes and an internship it is clearly not possible to teach students everything they will need to know for a career in GIS&T. Instead, emphasis will be placed on preparing students for work in entry level GIS jobs immediately upon graduation. In the process, the program will also try to teach as many of the national competencies as possible. This will insure that students are gaining employable skills along with a solid foundation in GIS&T.

The GIS Certificate Program at San Diego Mesa College is made up of the following four, 3-unit classes and a 1-4 unit internship or work experience class:

- GISG 110: Introduction to Mapping and GIS
- GISG 111: GIS - Intermediate Applications
- GISG 112: Spatial Analysis with GIS
- GISG 113: Advanced GIS Applications
- GISG 270: GIS Work Experience

These classes are taught in a computer lab using a combination of both lecture and lab hours. Since the program lacks a full-time faculty member, the teachers come from a pool of four or five part-time instructors.

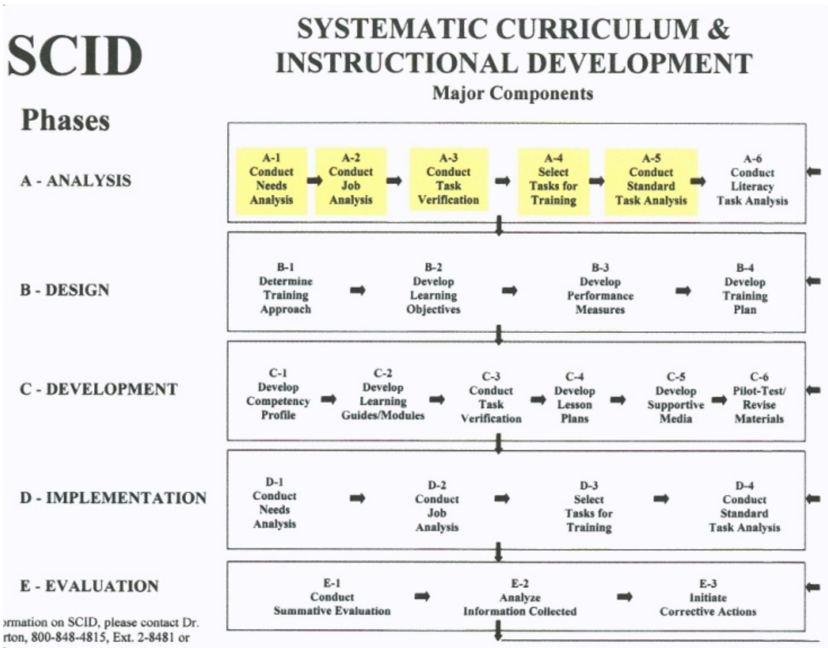
The goal is to revise this curriculum so that it addresses current workforce needs and prepares students for work in the field as entry level GIS Technicians. Clearly, the content of these classes must be carefully selected and arranged to provide the maximum benefit to most students. This is being accomplished through the use of the DACUM/SCID curriculum development model.

III. DACUM / SCID

Assessing workforce needs is critical to aligning courses and programs to meet these needs. The process however, can be very time consuming and expensive, especially for fields like GIS&T which are dynamic and constantly changing. One method that has been successfully used for developing a wide range of occupational training programs is the Systematic Curriculum and Instructional Development or "SCID" process (See Exhibit 1). It was developed by Dr. Robert Norton, from the Center on Education and Training for Employment at Ohio State University http://www.dacumohiostate.com. Its goal is to facilitate the development of instructional materials for training that captures the essential components of a given job or occupational area. The foundation for this model is the DACUM Research Chart which provides a detailed and graphic portrayal of the duties and tasks performed by workers in the field.

With funding from an NSF-ATE grant in 2004, San Diego Mesa College is using this methodology as a framework to develop its "Scalable Skills GIS Certificate Program". The goal of this project is to update the College's GIS curriculum in order to address the workforce needs of the GIS industry in San Diego County. The model provides a detailed structure for designing, developing, implementing and evaluating a skills-based curriculum. It is outlined in Exhibit 1:

Exhibit 1



DACUM Job Analysis: At San Diego Mesa College the SCID process began in 1999 with a Needs Assessment which was completed just prior to the creation of the GIS Program. This was followed in 2005, by a "DACUM Job Analysis". The job analysis involved a 2-day brainstorming workshop in which a focus group of 11 GIS Technicians worked with a DACUM facilitator to outline their principal job duties and responsibilities. At the end of the workshop they had created a DACUM chart which summarized the core duties, tasks and related competencies of an entry level GIS Technician in San Diego County. A portion of this chart is included as Exhibit 2. This chart described the skills that all graduates of the program should have in order to be successful as entry level GIS Technicians. Consequently, this document forms the basis of Mesa's "skills-based" GIS curriculum.

Exhibit 2

DACUM Research Chart for GIS Technician

	Duties	Tasks				
A	**Create GIS Data*** *(3)*	A-1 Define user(s) needs	A-2 Research existing data sources	A-3 Determine Data Structure e.g. database design, defining attributes, geometry, relating tables		A-4 Define Feature Relationships/ Behaviors
B	**Create Image Data**	B-1 Scan images *(E)*	B-2 Georeference imagery	B-3 Rectify images	B-4 Perform Image Analysis e.g. classification	
C	**Maintain GIS Data*** *(1)*	C-1 Develop a data maintenance schedule and procedures	C-2 Edit GIS data e.g. add, delete, update *(E)*	C-3 QA/QC Data *(E)*	C-4 Refresh/ Replace Layers e.g. imagery, thematic layers	C-5 Convert Data Format
D	**Conduct Spatial/ Nonspatial Analysis** *(4)* **(Vector, Raster)**	D-1 Create Models e.g. process & scientific models, scripts, flow charts	D-2 Preprocess Data e.g. generalize, subset	D-3 Conduct Geoprocessing e.g. clip, buffering, overlay, run models, geocode data		D-4 Generate Statistics e.g. descriptive, spatial
E	**Generate GIS Products*** *(2)* **(hard copy, electronic)**	E-1 Create maps *(E)*	E-2 Create Analysis Reports *(E)*	E-3 Create Charts *(E)*	E-4 Create Tables *(E)*	E-5 Generate mailing labels *(E)*
F	**Develop Software Applications**	F-1 Define User Needs	F-2 Select Application Design e.g. platform, language	F-3 Develop Custom Applications	F-4 Customize Commercial Software	F-5 Create Map Templates
		G-1 Establish	G-2 Organize File Structure		G-3 Archive /	G-4 Back up /

DACUM Research Chart for GIS Technician

General Knowledge and Skills
GIS Principles, Word Processing, Office Applications, Geometry, Trigonometry, Mathematics, Statistics Current GIS software: (MapInfo, SmallWorld, ArcGIS, ArcView, GeoMedia), Cartographic principles, Image processing (ERDAS), Photogrammetry, Programming languages (VBA), Land surveying, GPS, Reading engineering-grade plans, Databases, Census data, Windows operating system, General Geography,Data exchange procedures

Worker Behaviors
Initiative, Mentor, Sense of humor, Adaptability, Self-disciplined, Ethical, Willingness to learn, Self-motivated, Punctual, Organized, Detail-oriented, Open-minded

Abbreviations
COGO: Coordinate Geometry
QA/QC: Quality Assurance, Quality Control
PDA: Personal Digital Assistant

Tools, Equipment, Supplies & Materials
Plotters, Printers, Scanners, P.C.s, Calculators, Engineering/Architectural scales, Servers, GPS (Trimble-GeoXT, Sokkia-GR 1000, Static or RTK), Laptops, Tablet PCs, PDA, Pocket PC, Digitizer, Total Station, GIS Software: (ArcGIS, ArcIMS, ArcSDE, ArcPad, ArcGIS Extensions, Workstation ArcInfo, SmallWorld, MapInfo), MS Access, Auto CAD, Micro Station, IRASC, ERDAS Imagine, MS Office, MS Frontpage, Dreamweaver, Adobe Illustrator

Skills
Multi-tasking, Resourcefulness, Oral Communication, Writing, Technical writing, Printing legibly, Presentation, Cartographic Design, Analytical, Organizational, Time Management, Team Player, Ability to work independently, Facilitation, Computer, Network configuration, Data entry, Keyboarding

Future Trends and Concerns
Dominance of ESRI, lack of competition, Rapidly changing technology, Explosion of data, Public access to data, Security restrictions on data, Trend toward licensing & certification, Need for on-going training, Mobile computing (remote access), Data

Note: For a complete copy of this chart visit http://geoinfo.sdsu.edu/hightech/dacum.htm

It is interesting to note that graduates of Mesa's GIS Certificate Program will be working in positions similar to those held by members of the DACUM panel of GIS Technicians. As indicated in Table 1, all but one of these individuals had an undergraduate degree in Geography or a related field and two of them had Masters Degrees! In addition, most had supplemented their formal education by completing additional GIS certificates and ESRI classes. This indicates that, for many panel members, a GIS Certificate was complementary to their formal university education. Mesa's skills-based GIS Certificate Program is therefore likely to represent only one component of many students comprehensive GIS education.

Table 1

	Name	Title	Years in position	Organization	Education	Additional Training & Certificates
1	Nancy Ross	GIS Specialist – Mgmt Info. Services	12.5 yrs	City of Chula Vista	BA - Planning, UCSD	Multiple ESRI Courses
2	Drew Dowling	GIS Analyst	2 yrs	SanGIS	BS - Earth Science, USC	ESRI course in ArcObjects
3	Colleen Larsen	GIS/Mapping Specialist II	6 yrs	Padre Dam Water Dist.	BS - Geography	ESRI & Bentley Certificates in CAD & GIS
4	David Hulten	GIS Technician	1yr	City of Encinitas	BA - Geography	none
5	Dennis Larson	Senior GIS Technician	1yr	SANDAG	BA - Geography MA - Economics	GIS Certificate, SDSU
6	Sue Carnevale	Senior Regional Planner/GIS Analyst	24 yrs	SANDAG	BA - Geography, SDSU	ESRI GIS courses
7	Jason McNeil	GIS Technician II	3 yrs	City of Escondido	BS - Geography/GIS	ESRI training
8	Melanie Casey	GIS Analyst	6.5 yrs	County Plan & Land Use	BA - Geography	GIS Certificate
9	Fred McCamic	GIS Analyst	5 yrs	County Public Works	BA - Math, MA – Plan.	GIS Certificate
10	Gina Durizzi	Principal Survey Aide/GIS Coordinator	5 yrs	City of San Diego, Waste Water	BA - Geography	GIS Certificate, ESRI training, Microstation, Land Survey Training
11	Lisa Canning	Senior Engineering Aide, MWWD	2 yrs	City of San Diego, Waste Water	Student Landscape Architecture	UCSD Graphic Design Extension ¾ certificate, ESRI courses

Task Validation: Following the DACUM job analysis, the next step in the curriculum development process was to validate the results of this small panel of experts. This was done by sending their results to an additional 150 GIS Professionals in San Diego County.

Each recipient was asked to place themselves in the role of a GIS Technician and rate each of the 74 tasks according to the following criteria;

1. Do you perform this task?
2. How important is this task in the performance of your job as a GIS Technician?
3. What is the learning difficulty of this task?
4. Is this required at entry level?

This process was intended to generate a consensus on those tasks which are important, performed by entry level GIS Technicians and which are difficult to learn. Tasks which received an overall rating of 45 percent or greater were considered to be important based on these criteria and were therefore included in the curriculum. Tasks with a lower ranking on these four criteria were either left out or placed in classes which are not required for certification. Table 2 is a sample tabulation of this process.

Table 2

Results of Task Verification Survey
GIS Technician
San Diego Mesa College, Sept. 2005

	Perform	Importance	Learning Difficulty	Required	Overall	Include in Curriculum
Duty E: Generate GIS Products (hard copy, electronic)						
E-1 Create maps	98%	93%	64%	98%	88%	Y
E-4 Create tables	79%	77%	59%	89%	76%	Y
E-8 Distribute hard copy products	84%	76%	50%	80%	72%	Y
E-7 Distribute digital products	77%	73%	53%	68%	68%	Y
E-3 Create charts	65%	67%	57%	80%	67%	Y
E-2 Create analysis reports	68%	73%	70%	57%	67%	Y
E-6 Create graphic items (e.g. logos, headers, posters, exhibits)	73%	64%	57%	60%	64%	Y
E-5 Generate mailing labels	49%	52%	43%	63%	52%	Y
Summary; Duty E	**74%**	**72%**	**56%**	**74%**	**69%**	
Duty F: Develop Software Applications						
F-5 Create map templates	73%	69%	63%	78%	70%	Y
F-6 QA/QC software applications (e.g. beta test)	52%	51%	70%	43%	54%	Y
F-1 Define user software needs	43%	55%	71%	19%	47%	Y
F-4 Customize commercial software	34%	57%	78%	10%	45%	Y
F-7 Build Help files	31%	44%	64%	35%	44%	N
F-8 Enhance existing custom applications	33%	46%	79%	10%	42%	N
F-3 Develop software applications	23%	49%	80%	9%	40%	N
F-2 Determine application design format (e.g. platform, language)	29%	50%	75%	4%	39%	N
Summary: Duty F	**40%**	**53%**	**73%**	**26%**	**48%**	
Duty G: Manage GIS Data						
G-2 Organize file structure (eg create directories, perform data/directory housekee	82%	80%	55%	69%	71%	Y
G-3 Archive / retrieve data	79%	70%	50%	68%	67%	Y
G-4 Back up / restore data	61%	69%	51%	60%	60%	Y
G-5 Distribute data according to organizational policy	60%	64%	46%	62%	58%	Y
G-1 Establish data custodianship	37%	60%	63%	28%	47%	Y
G-6 Assign data/database permissions	34%	56%	60%	6%	39%	N

Task Analysis: Once the core job tasks were identified through Task Validation, they were then evaluated through a process known as "Task Analysis". This process, involved taking each task and breaking it down into a series of steps. Each step was then listed and described, along with any necessary tools or equipment as well as related resources such as books, websites, or datasets (See Table 3).

Table 3

STANDARD TASK ANALYSIS FORM 12/13/2007 Validation Rating 63% Duty: A: Create / Acquire GIS Data Task: A16 - Collect Field Location Data via GPS

STEPS	Activity	TOOLS, EQUIPMENT, MATERIALS & SUPPLIES	RELATED RESOURCES (e.g. articles, books, websites, data, exercises)
Observe demonstration of GPS setup, GPS menus, satellite constellation, scale, zoom, pan, compass direction functionality, and data collection	Complete questions on key points of GPS use	Garmin GPS Map 60, software and cables; Google Earth Plus or higher	http://www.ca.uky.edu/mueller/pls468g/gis/gps_module.pdf Student handout of relevant directions for activities performed in this exercise and/or Garmin instruction booklet and/or digital direction file (including menu navigation, preferred coordinate system, and data collection techniques)
Receive GPS units and prepare GPS units for use according to GPS instructions	Demonstrate correct GPS setup according to instructions, including coordinate system		Reference online resources, books, articles
Receive description of features for which data will be collected (eg: signs, plants, benches, etc.)			
Collect waypoints outside of classroom for these features, with minimum of 4 satellites distributed evenly (PDOP??)	Record satellite strength and positional accuracy from GPS		
In classroom observe demonstration of Garmin software, displaying data in Google Earth and download and export of data to shapefile	Answer questions on key points concerning data downloading and exporting		
Connect GPS to classroom computer using Garmin cable	Window display demonstrates that GPS is properly connected		
Display GPS data in Google Earth and evaluate accuracy	Observe locational accuracy of waypoints		
Use Garmin software to export data in shapefile format	Shapefile saved to drive		Imagery of Mesa Cllege campus
In ArcGIS display shapefile with campus imagery and streets	Create ArcMap layout demonstrating principles of cartography		

Task analysis provided detailed information on what students should be doing in the classroom, what tools or equipment would be needed as well as a selection of resources that are available to facilitate their work.

Training Approach: Following Task Analysis the next step in the SCID curriculum development model was to determine a training approach. For this, a "competency-based" training approach was selected in order to insure that students acquire both the knowledge and skills required for them to succeed on the job. According to the SCID model, a competency-based training program requires the following:

- That competencies be made public
- That the criteria for assessment is clear
- That different learning styles & abilities are accommodated
- That task performance is the primary method of assessment

- That learners are allowed to progress at their own speed

The implementation of this competency based approach will be explored in more detail after the learning objectives and curriculum have been finalized.

Learning Objectives: Following the selection of a training approach, the next step involves developing learning objectives for the core DACUM tasks. Learning objectives specify the desired learning outcomes of teaching activities. They are a critical component of any course outline since they form the basis of what is actually learned in a course. They are also required to develop student assessment materials and for determining course equivalencies.

Two resources were initially used as a potential source for these learning objectives; the 2006, UCGIS Body of Knowledge and the 2001, University of Southern Mississippi's Workforce Development Model for Geospatial Technology. Individual DACUM tasks were matched with the appropriate units and competencies from these documents. (see Table 4). It became evident that while geospatial competencies were useful in identifying important general knowledge and skill areas, they were not detailed enough to be considered learning objectives. The Body of Knowledge, on the other hand, included a comprehensive set of GIS&T learning objectives for each unit. Learning objectives from the Body of Knowledge were therefore selected to be used as the basis for the new curriculum.

In order to use learning objectives from the Body of Knowledge in the new curriculum it was first necessary to map them to the DACUM tasks. Having identified over 60 core DACUM tasks and with more than 1,600 Body of Knowledge learning objectives however, it soon became clear that something had to be done to streamline this process. This was accomplished by consolidating the DACUM chart into a summary document.

Summary DACUM Chart with Conceptual Foundations

Many tasks in the DACUM chart for GIS Technicians are closely related to one another and often fall within similar work categories. For example A15: Create Metadata and C8: Update Metadata, are separate tasks however both require the same knowledge and skills and both are completed as part of the data creation or update process. Likewise, A1: Research Available Data and A2: Define Data Requirements are closely related and are often conducted together at the beginning of a project. To eliminate this redundancy and simplify the task of mapping DACUM tasks to the Body of Knowledge, the original DACUM chart was summarized into seven general duty categories and forty-eight task groupings. In addition, a new duty category was added to this chart called Conceptual Foundations. This category was considered necessary since many of the tasks listed in the DACUM chart required an initial understanding of certain basic geographic and geospatial concepts that are listed in the Body of Knowledge. The revised chart is included as Table 5.

Table 4

DACUM Steps, Body of Knowledge Units & Geospatial Competencies

Task A1: Define Data Requirements

Step	Description	UCGIS Body of Knowledge Units	University of Mississippi Geospatial Tech. Competency
1	Acquire or create a written description of the project	DA2 Project definition	20 Industry Understanding 36 Technical Writing* 8 Communication*
2	Discuss with others involved	CF3 Domains of geographic information* CV2 Data considerations* DA3 Resource planning DM1 Basic storage and retrieval structures	15 Feedback Skills* 28 Problem-Solving Skills* 29 Questioning
3	Anticipate the outcome to determine the data requirements	DM2 Database management systems*	12 Creative Thinking* 16 Geology Applications 2 Ability to see the "Big Picture"* 32 Research Skill 39 Visioning*
4	Determine the data types (raster, vector, 3D, database) requirements	DM4 Vector and object data models*	34 Spatial Information Processing 37 Technological Literacy*
5	Determine data attributes requirements	DA1 The scope of GI S&T system design DA2 Project definition DA3 Resource planning DA4 Database design*	16 Geology Applications 17 Geospatial Data Processing Tools
6	Determine data quality requirements	DA5 Analysis design GD6 Data quality*	16 Geology Applications 26 Performance Analysis and Evaluation 3 Business Understanding
7	Determine data coordinates systems	DN1 Representation transformation* GD3 Georeferencing systems* GD4 Datums* GD5 Map projections*	17 Geospatial Data Processing Tools
8	Demonstrate an understanding of the project data requirements	CV4 Graphic representation techniques	28 Problem-Solving Skills* 36 Technical Writing* 8 Communication*

Note: * indicates core units and core competencies

Table 5

SUMMARY DACUM CHART FOR GIS TECHNICIAN
With Conceptual Foundations

D U T I E S	CONCEPTS & T A S K S					
CONCEPTUAL FOUNDATIONS (CF)	Geography as a Foundation for GIS, Earth Geometry	Projections, Coordinate Systems, Datums	Domains of Geographic Information	History & Trends in GIS	Vector & Object Data Models	Data classification
CREATE & ACQUIRE DATA (C&AD)	A1, A2 Research & define data requirements	A8, A9 Perform tablet & on-screen digitization	A10 Geocode address data	A13 Populate GIS feature attributes	A14 QA&QC Data	A15, C8 Create & update metadata
	A16, A17 Collect field location & attribute data with GPS		B1 Scan hard copy maps	B2, B3 Georeference & rectify digital imagery	C3 Edit GIS data (e.g. add, delete, update)	
MAINTAIN & MANAGE DATA (M&MD)	A4 Develop database(s) (e.g. define geometry & attributes)	A5, A6 Define feature relationships & behavior (e.g. relate tables, subtypes, domains, relationship class)		A11,A12,C6 Determine data compatibility & perform data conversions (e.g. projections)		C4 QA&QC Data
	C5 Refresh & replace layers (e.g. imagery, thematic layers)	C7 Conduct database performance tuning (e.g. compress, build stats, index)	G1 Establish data custodianship	G3, G4 Backup, archive, retrieve & restore data	G2 Organize file structure (e.g. create directories, perform data & directory housekeeping)	G5 Distribute data according to organizational policy
ANALYZE DATA (AD)	B4 Perform image analysis (e.g. classification)	D1, D2 Create models & scripts (e.g. process & scientific models, flow charts)	D3 Pre-process data (e.g. generalize, subset)	D4 Conduct geoprocessing (e.g. clip, buffer, overlay, run models)	D5 Generate statistics (e.g. descriptive, spatial)	D7, D6 Interpret results QA&QC Data
GENERATE PRODUCTS (GP)	E1,F5 Create maps & templates	E2 Create analysis reports	E3, E4, E5 Create tables, charts & mailing labels	E6 Create graphics (e.g. logos, posters, headers, exhibits)		E7, E8 Distribute digital & hard copy products
TECHNICAL SUPPORT (TS)	F1 Define user software need	F6 Customize & QA&QC commercial software Applications	H1 Resolve user technical problems (software & hardware)	H2 Install \ update software (e.g. enhancements, service packs)	H4 Train & cross-train GIS end users	
MANAGE PROJECTS (MP)	H3, I2 Write / review technical guides & reports	I6 Maintain equipment, supplies, contracts	I8 Supervise interns	I3, I4 Coordinate GIS projects & prepare cost, time & equipment estimates	I5, I9, J1, J2 Represent & promote GIS (e.g. at committees, user groups, conf.)	J3, J4 Take advanced technical training & education courses

IV THE UCGIS BODY OF KNOWLEDGE

The UCGIS Body of Knowledge, published by the Association of American Geographers (AAG) in 2006, seeks to define what constitutes the field of Geographic Information Science & Technology (GIS&T). Under development since 1998, it includes contributions from scholars from many of the more than 80 institutions that UCGIS represents. It is intended to be used as a resource for GIS&T course and curriculum planners at both the university and community college level and to serve as the basis for professional certification, program accreditation and articulation agreements.

The Body of Knowledge establishes a set of ten general knowledge areas which constitute the entire domain of GIS&T. Each knowledge area is divided into a set of units which are identified as either "core" or "elective". There are a total of twenty-six core units and forty-seven elective units. The core units are identified as those which "all graduates of a degree or certificate program should be able to demonstrate some level of mastery". Each unit is then divided into topics which represent specific concepts, methodologies or techniques. Finally, each topic is defined by one or more educational or learning objective. These are statements which describe actions or activities that students are required to perform in order to demonstrate mastery of the topic. The Body of Knowledge currently has a total of 329 topics and over 1,600 educational or learning objectives!

Since the DACUM and SCID process require the creation of learning objectives for the critical tasks performed by a GIS Technician and the BofK includes a comprehensive set of learning objectives for the field of GIS&T, it seemed logical to try and match these learning objectives with the DACUM tasks. This would make it possible to use industry standard criteria to define critical DACUM tasks. Bringing the BofK and DACUM together into a single curriculum would have the added benefit of creating a program which is compatible with others based on the UCGIS Body of Knowledge.

Mapping the Body of Knowledge to the Summary DACUM Chart

In its current state the Body of Knowledge offers little help or guidance to those involved in developing a Community College GIS Certificate program. While the editors recognized the importance of defining "educational pathways and supporting materials" for institutions other than four-year Universities, they decided to defer this effort until after this document had been published. The report recognizes that "two-year institutions are well-positioned to prepare students for entry-level positions that involve routine use of geospatial technologies" however it does not explicitly identify the learning objectives which are appropriate at this level.

Since most of the learning objectives in the Body of Knowledge are intended for students in an undergraduate or graduate level University program, it was challenging to identify those objectives that would be appropriate for students in a lower level program. Nevertheless, an effort was made to review the topics and learning objectives and to select those which were considered suitable for a community college program. In addition to these, at least one basic learning objective for every "core topic" was also included in order to comply with the statement that "all graduates of a degree or certificate program should be able to demonstrate some level of mastery" of these topics. This process resulted in a list of 397 learning objectives taken from forty nine units in the Body of Knowledge (See Appendix).

Table 6 lists all the knowledge areas and units in the Body of Knowledge as well as those units that are included in the new curriculum. Core units are shown in bold. Each unit includes a set of topics which are then further broken down into learning objectives. The values in brackets represent the number of topics from each unit that are included in the new curriculum.

Table 6

GIS&T BODY OF KNOWLEDGE
KNOWLDEGE AREAS AND UNITS
(& GIS Technician Units)

AM. Analytical Methods	**GC. Geocomputation**
AM1 Academic and analytical origins (6)	GC1 Emergence of geocomputation (2)
AM2 Query operations and query languages (6)	GC2 Computational aspects and neurocomputing
AM3 Geometric measures (8)	GC3 Cellular Automata (CA) models
AM4 Basic analytical operations (14)	GC4 Heuristics
AM5 Basic analytical methods (9)	GC5 Genetic algorithms (GA)
AM6 Analysis of surfaces	GC6 Agent-based models
AM7 Spatial statistics	GC7 Simulation modeling
AM8 Geostatistics	GC8 Uncertainty
AM9 Spatial regression and econometrics	GC9 Fuzzy sets
AM10 Data mining	
AM11 Network analysis	**GD. Geospatial Data**
AM12 Optimization and location-allocation modeling	**GD1 Earth geometry (7)**
	GD2 Land partitioning systems (2)
CF. Conceptual Foundations	**GD3 Georeferencing systems (15)**
CF1 Philosophical foundations	**GD4 Datums (2)**
CF2 Cognitive and social foundations (7)	**GD5 Map projections (10)**
CF3 Domains of geographic information (10)	**GD6 Data quality (10)**
CF4 Elements of geographic information (7)	**GD7 Land surveying and GPS (12)**
CF5 Relationships (1)	GD8 Digitizing (3)
CF6 Imperfections in geographic information	GD9 Field data collection (5)
	GD10 Aerial imaging and photogrammetry (9)
CV. Cartography and Visualization	**GD11 Satellite and shipboard remote sensing (9)**
CV1 History and trends (3)	**GD12 Metadata, standards, and infrastructures (18)**
CV2 Data considerations (14)	
CV3 Principles of map design (18)	**GS. GI S&T and Society**
CV4 Graphic representation techniques (14)	GS1 Legal aspects (1)
CV5 Map production (3)	GS2 Economic aspects
CV6 Map use and evaluation (34)	GS3 Use of geospatial information in the public sector
	GS4 Geospatial information as property
DA. Design Aspects	GS5 Dissemination of geospatial information
DA1 The scope of GI S&T system design (4)	**GS6 Ethical aspects of geospatial information & tech. (4)**
DA2 Project definition (3)	GS7 Critical GIS
DA3 Resource planning (9)	
DA4 Database design (5)	**OI. Organizational and Institutional Aspects**
DA5 Analysis design	OI1 Origins of GI S&T
DA6 Application design (5)	O2 Managing the GI system operations and infrastructure
DA7 System implementation (2)	OI3 Organizational structures and procedures
	OI4 GI S&T workforce themes
DM. Data Modeling	**OI5 Institutional and inter-institutional aspects (13)**
DM1 Basic storage and retrieval structures (2)	**OI6 Coordinating organizations (national/international) (10)**
DM2 Database management systems (5)	
DM3 Tessellation data models (18)	
DM4 Vector and object data models (19)	
DM5 Modeling 3D, temporal, & uncertain phenomena (4)	
DN. Data Manipulation	**K E Y**
DN1 Representation transformation (18)	**KA. Knowledge Area**
DN2 Generalization and aggregation (15)	Core Units in bold

DN3 Transaction management of geospatial data (5)	GIS Technician Units (count)

Table 7 identifies the distribution of these learning objectives with respect to the Summary DACUM duty categories. It is evident from this table that the Body of Knowledge addresses certain DACUM tasks more completely than others. A total of 110, or 29 percent of the learning objectives, fall into the category of conceptual foundations and 93, or 23 percent of the objectives, involve data analysis. This signifies the importance of these topics in the Body of Knowledge. Another 85, or 21 percent of the objectives, involve creating and acquiring data and 64, or 16 percent of the learning objectives involve product generation. The remaining 45 learning objectives involve maintaining and managing data, providing technical support and managing projects.

Table 7

DACUM Duty Category	BofK Learning Objectives	%
Conceptual Foundations	110	28.7%
Analyze Data	93	23.4%
Create & Acquire Data	85	21.4%
Generate Products	64	16.1%
Maintain & Manage Data	29	7.3%
Technical Support	12	3.0%
Manage Projects	4	1.0%
Total Units	397	100.0%

By comparison, Table 8 shows the actual distribution of DACUM tasks within the Summary DACUM chart. Twenty-four percent of the tasks involve creating and acquiring data, 22 percent involve maintaining and managing data, 19 percent involve managing projects, 14 percent involve generating products, 13 percent involve analyzing data and 8 percent involve technical support. It will be important to factor in this discrepancy when mapping learning objectives to the curriculum.

Table 8

DACUM Duty Category	DACUM Tasks	%
Create & Acquire Data	15	23.8%
Maintain & Manage Data	14	22.2%
Manage Projects	12	19.0%
Generate Products	9	14.3%
Analyze Data	8	12.7%
Technical Support	5	7.9%
Conceptual Foundations	0	0%
Total Tasks	63	100.0%

What comes next?

The next step in the curriculum development process will involve organizing and aligning the learning objectives with core DACUM skills. Learning objectives will also be identified as either performance objectives or enabling objectives. Performance objectives can be identified as those that specify the behavior required of a performer while enabling objectives support the achievement of these behaviors. They do so by either helping learners gain the required knowledge or by providing them with an opportunity to practice what they have learned.

The learning objectives will then be sequenced to insure that fundamental concepts and skills are covered prior to the more advanced level subjects. Gaps will be identified and new learning objectives will be created to fill them. In addition, duplicate or closely related learning objectives, which offer minimal marginal benefit towards achieving the core DACUM skills, will be excluded from the curriculum.

At this point the learning objectives can be mapped to the five classes in Mesa's GIS Certificate program. Of course, additional edits and course modifications will no doubt be required to meet both time and topical constraints of these classes. With the courses developed and a complete set of learning objectives clearly organized and defined for each, performance measures can be then be generated. These should address the three critical learning domains of knowledge assessment, attitude or affective performance assessment and skills or performance testing. These assessment instruments will be critical to accurately measure the level of student success in the program.

Detailed learning guides or learning aids should also be developed to assist instructors with the highly complex task of providing competency based education (CBE) in GIS. Highly structured, well conceived and carefully developed materials are critical in order for this program to function effectively. This is particularly important for programs such as this where all of the instructors are part-time or adjunct. These instructors typically lack the time to develop an extensive set of quality teaching materials for their classes. In addition, they are generally not paid for time spent developing such materials.

After the revised training program has been launched it will be important to continually evaluate its relevance and effectiveness over time. This can be done by monitoring student job placements, updating the DACUM chart, incorporating future changes made to the Body of Knowledge and seeking regular feedback from industry advisors. Updates and modifications to the curriculum should continue throughout the life of the program to ensure that it continually adapts to changes in technology as well as workforce and employer needs.

V CONCLUSION

To upgrade the quality of its GIS Certificate program and develop a skills-based GIS curriculum, San Diego Mesa College is relying upon two valuable and complementary resources: the DACUM/SCID curriculum development process and the UCGIS Body of Knowledge. DACUM/SCID is being used to identify workforce skills and translate them into a curriculum while the Body of Knowledge will provide both the conceptual foundations and the learning objectives for the new program.

The DACUM/SCID curriculum development process proved to be an effective and logical way of identifying the critical skills required for students in this field and translating them into a curriculum. Core skills, based directly on input from industry representatives, were scientifically validated, ranked and analyzed to create a summary DACUM chart. This chart, which was amended to include important background knowledge areas, forms the foundation of the new curriculum. It is being used, along with information from the task analysis process and the Body of Knowledge, to generate courses for the new skills-based GIS Certificate Program.

The Body of Knowledge provides curriculum developers with a detailed inventory of educational or learning objectives for the field of GIS&T. This resource is well organized into general knowledge areas, core and elective units and topics. In its current state however, it emphasizes skills and competencies required for graduation from a four-year undergraduate or post-graduate institution. No guidelines are provided to assist those working at the Community College level in choosing appropriate units, topics and competencies for their students.

Using the revised DACUM chart, a set of approximately 400 educational objectives from the Body of Knowledge were identified for use in Mesa’s new skills based GIS program. These competencies will be further evaluated, organized and consolidated into classes for the new skills-based curriculum.

Appendix

BODY OF KNOWLEDGE	DACUM
AM. Analytical Methods	
AM1 Academic and analytical origins	
AM1-1 Academic foundations	
Differentiate geospatial data analysis from non-spatial data analysis	**AD**
AM1-2 Analytical approaches	
Explain what is special (i.e., difficult) about geospatial data analysis and why some traditional statistical analysis techniques are not suited to geographic problems	**A D**
Compare and contrast spatial statistical analysis, spatial data analysis, and spatial modeling	**A D**
Compare and contrast spatial statistics and map algebra as two very different kinds of data analysis	**A D**
Compare and contrast the methods of analyzing aggregate data as opposed to methods of analyzing a set of individual observations	**A D**
Outline the sequence of tasks required to complete the analytical process for a given spatial problem	**A D**
AM2 Query operations and query languages	
AM2-2 Structured Query Language (SQL) and attribute queries	
Create an SQL query to retrieve elements from a GIS	**A D**
Define basic terms of query processing (e.g., SQL, primary and foreign keys, table join)	**A D**
Compare and contrast attribute query and spatial query	**A D**
State questions that can be solved by selecting features based on location or spatial relationships	**A D**
Construct a query statement to search for a specific spatial or temporal relationship	**A D**
Construct a spatial query to extract all point objects that fall within a polygon	**A D**
***AM3 Geometric measures (core unit)**	
***AM3-1 Distances and lengths**	
Outline the implications of differences in distance calculations on real world applications of GIS, such as routing and determining boundary lengths and service areas	**A D**
***AM3-2 Direction**	
Define “direction” and its measurement in different angular measures	**A D**
***AM3-3 Shape**	
Exemplify situations in which the centroid of a polygon falls outside its boundary	**A D**
***AM3-4 Area**	
Demonstrate how the area of a region calculated from a raster data set will vary by resolution and orientation	**A D**

BODY OF KNOWLEDGE	DACUM
***AM3-5 Proximity and distance decay**	
Describe real world applications where distance decay is an appropriate representation of the strength of spatial relationships (e.g., shopping behavior, property values)	**A D**
Describe real world applications where distance decay would NOT be an appropriate representation of the strength of spatial relationships (e.g., distance education, commuting, telecommunications)	**A D**
***AM3-6 Adjacency and connectivity**	
List different ways connectivity can be determined in a raster and in a polygon dataset	**A D**
Describe real world applications where adjacency and connectivity are a critical component of analysis	**A D**
***AM4 Basic analytical operations (core unit)**	
***AM4-1 Buffering**	
Compare and contrast raster and vector definitions of buffers	**A D**
Explain why a buffer is a contour on a distance surface	**A D**
Outline circumstances in which buffering around an object is useful in analysis	**A D**
***AM4-2 Overlay**	
Explain why the process “dissolve and merge” often follows vector overlay operations	**A D**
Explain what is meant by the term “planar enforcement”	**A D**
Outline the possible sources of error in overlay operations	**A D**
Exemplify applications in which overlay is useful, such as site suitability analysis	**A D**
Compare and contrast the concept of overlay as it is implemented in raster and vector domains	**A D**
Demonstrate how the geometric operations of intersection and overlay can be implemented in GIS	**A D**
Demonstrate why the registration of datasets is critical to the success of any map overlay operation	**A D**
Formalize the operation called map overlay using Boolean logic	**A D**
***AM4-3 Neighborhoods**	
Explain how the range of map algebra operations (local, focal, zonal and global) relate to the concept of neighborhoods	**A D**
***AM4-4 Map algebra**	
Describe how map algebra performs mathematical functions on raster grids	**A D**
Describe a real modeling situation in which map algebra would be used (e.g., site selection, climate classification, least-cost path)	**A D**
Explain the categories of map algebra operations (i.e., local, focal, zonal, and global functions)	**A D**

BODY OF KNOWLEDGE	DACUM
***AM5 Basic analytical methods (core unit)**	
***AM5-1 Point Pattern Analysis**	
Identify the various ways point patterns may be described	**A D**
***AM5-2 Kernels and density estimation**	
Differentiate between kernel density estimation and spatial interpolation	**A D**
***AM5-3 Spatial cluster analysis**	
Identify several cluster detection techniques and discuss their limitations	**A D**
***AM5-4 Spatial interaction**	
Differentiate between the gravity model and spatial interaction models	**A D**
***AM5-5 Analyzing Multidimensional attributes**	
Relate plots of multidimensional attribute data to geography by equating similarity in data space with proximity in geographical space	**A D**
***AM5-6 Cartographic modeling**	
Describe the difference between prescriptive and descriptive cartographic models	**A D**
Discuss the origins of cartographic modeling with reference to the work of Ian McHarg	**A D**
***AM5-7 Multi-criteria evaluation**	
Describe the implementation of an ordered weighting scheme in a multiple-criteria aggregation	**A D**
***AM5-8 Spatial process models**	
Discuss the relationship between spatial processes and spatial patterns	**A D**
AM6 Analysis of surfaces	
AM7 Spatial statistics	
AM8 Geostatistics	
AM9 Spatial regression and econometrics	
AM10 Data mining	
AM11 Network analysis	
AM12 Optimization and location-allocation modeling	
CF. Conceptual Foundations	
CF1 Philosophical foundations	
CF2 Cognitive and social foundations	

BODY OF KNOWLEDGE	DACUM
CF2-3 Geography as a foundation for GIS	
Define the properties that make a phenomenon geographic	**C F**
Describe some insights that a spatial perspective can contribute to a given topic	**C F**
Explore the history of geography including (but not limited to) Greek and Roman contributions to geography (Eratosthenes, Strabo, Ptolemy), geography and cartography in the age of discovery, military geography, and geography since the quantitative revolution	**C F**
Justify a chosen position on which disciplines should have as important a role in GI S&T as geography	**C F**
Discuss the differing denotations and connotations of the terms spatial, geographic, and geospatial	**C F**
CF2-5 Common-sense geographies	
Effectively communicate the design, procedures, and results of GIS projects to non-GIS audiences (clients, managers, general public)	**T S**
Collaborate with non-GIS experts who use GIS to design applications that match common-sense understanding to an appropriate degree	**T S**
***CF3 Domains of geographic information (core unit)**	
***CF3-1 Space**	
Define the four basic dimensions or shapes used to describe spatial objects (i.e., points, lines, regions, volumes)	**C F**
Differentiate between absolute and relative descriptions of location	**C F**
***CF3-2 Time**	
Select the temporal elements of geographic phenomena that need to be represented in particular GIS applications	**C F**
***CF3-3 Relationships between space and time**	
Compare and contrast the characteristics of spatial and temporal dimensions	**C F**
***CF3-4 Properties**	
Define Stevens' four scales of measurement (nominal, ordinal, interval, ratio)	**C F**
Recognize attribute domains that do not fit well into Stevens' four scales of measurement (nominal, ordinal, interval, ratio), such as cycles, indexes, and hierarchies	**C F**
Describe particular geographic phenomena in terms of attributes	**C F**
Characterize the domains of attributes in a GIS, including continuous and discrete, qualitative and quantitative, absolute and relative	**C F**
Determine the proper uses of attributes based on their domains	**C F**
Recognize situations and phenomena in the landscape which cannot be adequately represented by formal attributes, such as aesthetics	**C F**

BODY OF KNOWLEDGE	DACUM
***CF4 Elements of geographic information (core unit)**	
***CF4-1 Discrete entities**	
Identify the types of features that need to be modeled in a particular GIS application or procedure	**C F**
Identify phenomena that are difficult or impossible to conceptualize in terms of entities	**C F**
Describe the difficulties in modeling entities with ill-defined edges	**C F**
Evaluate the influence of scale on the conceptualization of entities	**C F**
***CF4-2 Events and processes**	
Compare and contrast the concepts of event and process	**C F**
***CF4-3 Fields in space and time**	
Define a field in terms of properties, space, and time	**C F**
***CF4-4 Integrated models**	
Determine whether phenomena or applications exist that are not adequately represented in an existing comprehensive model	**C F**
CF5 Relationships	
CF5-1 Categories	
Create or use GIS data structures to represent categories, including attribute columns, layers/themes, shapes, legends, etc.	**C F**
CF6 Imperfections in geographic information	
CV. Cartography and Visualization	
CV1 History and trends (1)	
CV1-1 History of cartography	
Describe how compilation, production, and distribution methods used in map making have evolved	**C F**
Explain how technological changes have affected cartographic design and production	**C F**
CV1-2 Technological transformations	
Discuss the impact that mapping on the Web via applications, such as Google Earth, have had on the practice of Cartography	**C F**
***CV2 Data considerations (core unit)**	
***CV2-1 Source materials for mapping**	
List the data required to compile a map that conveys a specified message	**C & A D**
List the data required to explore a specified problem	**C & A D**

BODY OF KNOWLEDGE	DACUM
Identify the types of attributes that will be required to map a particular distribution for selected geographic features	C & A D
Compile a map using at least three data sources	C & A D
Assess the data quality of a source dataset for appropriateness for a given mapping task, including an evaluation of the data resolution, extent, currency or date of compilation, and level of generalization in the attribute classification	C & A D
Explain how data acquired from primary sources, such as satellite imagery and GPS, differ from data compiled from maps, such as DLGs	C & A D
Describe the copyright issues involved in various cartographic source materials	C & A D
***CV2-2 Data abstraction: classification, selection, and generalization**	
Discuss advantages and disadvantages of various data classification methods for choropleth mapping, including equal interval, quantiles, mean-standard deviation, natural breaks, and “optimal” methods	C F
Demonstrate how different classification schemes produce very different maps from a single set of interval or ratio data	C F
***CV2-3 Projections as a map design issue**	
Diagnose an inappropriate projection choice for a given map and suggest an alternative	G P
Identify the map projections commonly used for certain types of maps	G P
Identify the most salient projection property of various generic mapping goals (e.g., choropleth map, navigation chart, flow map, etc.)	G P
Explain why certain map projection properties have been associated with specific map types	G P
Select appropriate projections for world or regional scales that are suited to specific map purposes and phenomena with specific directional orientations or thematic areal aggregations	G P
***CV3 Principles of map design (core unit)**	
***CV3-1 Map design fundamentals**	
List the major factors that should be considered in preparing a map	G P
Discuss the differences between maps that use the same data but are for different purposes and intended audiences	G P
Critique the graphic design of several maps in terms of balance, legibility, clarity, visual contrast, figure-ground organization, and hierarchal organization	G P
Design maps that are appropriate for users with vision limitations	G P
Describe differences in design needed for a map that is to be viewed on the Internet versus as a 5x7 foot poster, including a discussion of the effect of viewing distance, lighting, and media type	G P
Critique the layout of several maps, taking into account the map audience and purpose and the graphic design (visual balance, hierarchy, figure-ground), as well as the map components (north arrow, scale bar, and legend)	G P
Prepare different map layouts using the same map components (main map area, inset maps, titles, legends, scale bars, north arrows, grids and graticule) to produce maps with very distinctive purposes	G P

BODY OF KNOWLEDGE	DACUM
Prepare different maps using the same data for different purposes and intended audiences (e.g. expert and novice hikers)	G P
***CV3-2 Basic concepts of symbolization**	
Illustrate how a single geographic feature can be represented by various graphic primitives e.g. land surface as a set of elevation points, as contour lines, as hypsometric layers or tints, and as a hillshaded surface)	G P
Design map symbols with sufficient contrast to be distinguishable by typical users	G P
***CV3-3 Color for cartography and visualization**	
List the range of factors that should be considered in selecting colors	G P
***CV3-4 Typography for cartography and visualization**	
Describe the role of labels in assisting readers in understanding feature locations (e.g., label to the right of point, label follows line indicating its position, area label assists understanding extent of feature and feature type)	G P
Compare and contrast the strengths and limitations of methods for automatic label placement	G P
Compare and contrast the relative merits of having map labels placed dynamically versus having them saved as annotation data	G P
Position labels on a map to name point, line, and area features	G P
Apply the appropriate technology to place name labels on a map using a geographic names database	G P
Set type font, size, style and color for labels on a map by applying basic typography design principles	G P
Solve a labeling problem for a dense collection of features on a map using minimal leader lines	G P
CV4 Graphic representation techniques (29)	
CV4-1 Basic thematic mapping methods	
Explain why choropleth maps should (almost) never be used for mapping count data and suggest alternative methods for mapping count data	G P
Evaluate the strengths and limitations of each of the following methods: choropleth, dasymetric, proportioned symbol, graduated symbol, isoline, dot, cartogram, and flow map	G P
Choose suitable mapping methods for each attribute of a given type of feature in a GIS (e.g., roads with various attributes such as surface type, traffic flow, number of lanes, direction such as one-way, etc.)	G P
Select base information suited to providing a frame of reference for thematic map symbols (e.g., network of major roads and state boundaries underlying national population map)	G P
Create maps using each of the following methods: choropleth, dasymetric, proportioned symbol, graduated symbol, isoline, dot, cartogram, and flow map	G P
Create well-designed legends using the appropriate conventions for the following methods: choropleth, dasymetric, proportioned symbol, graduated symbol, isoline, dot, cartogram, and flow map	G P

BODY OF KNOWLEDGE	DACUM
CV4-3 Dynamic and interactive displays	
Critique the interactive elements of an online map	**G P**
Develop a useful interactive interface and legend for an animated map	**G P**
Create an animated map for a specified purpose	**G P**
Create an interactive map suitable for a given audience	**G P**
CV4-5 Web mapping and visualizations	
Critique the user interface for existing Internet mapping services	**G P**
Construct a Web page that includes an interactive map	**G P**
CV4-6 Virtual and immersive environments	
Discuss the nature and use of virtual environments such as Google Earth	**G P**
CV4-8 Visualization of temporal geographic data	
Describe how an animated map reveals patterns not evident without animation	**G P**
CV5 Map production (15)	
CV5-1 Computational issues in cartography and visualization	
Differentiate between GIS and graphics software tools for mapping and those for visualization purposes	**G P**
CV5-2 Map Production	
Differentiate among the various raster map outputs (JPG, GIF, TIF) and various vector formats (PDF, Adobe Illustrator Postscript)	**G P**
Compare and contrast the file formats suited to presentation of maps on the Web (e.g., PDF and JPEG) to those suited to publication in high resolution contexts (e.g., TIFF, PDF, Adobe Illustrator Postscript)	**G P**
*** CV6 Map use and evaluation (core unit)**	
***CV6-1 The power of maps**	
Discuss how the choices used in the design of a road map will influence the experience visitors may have of the area	**G P**
Explain how legal issues impact the design and content of such special purpose maps as subdivision plans, nautical charts and cadastral maps	**G P**
Exemplify maps that illustrate the provocative, propaganda, political, and persuasive nature of maps and geospatial data	**G P**
Demonstrate how different methods of data classification for a single dataset can produce maps that will be interpreted very differently by the user	**G P**
Construct two maps about a conflict or war producing one supportive of each side’s viewpoint	**G P**

BODY OF KNOWLEDGE	DACUM
***CV6-2 Map reading**	
Discuss the pros and cons of using conventional symbols (e.g., blue is water, green is vegetation, Swiss cross is a hospital) on a map	**G P**
Explain how the anatomy of the eye and its visual sensor cells affect how one sees maps, in terms of attention, acuity, focus, and color	**G P**
Explain how memory limitations effect map reading tasks	**G P**
Find specified features on a topographic map (e.g., gravel pit, mine entrance, well, land grant)	**G P**
Match map labels to the corresponding features	**G P**
Match the symbols on a map to the corresponding explanations in the legend	**G P**
Execute a well designed legend that facilitates map reading	**G P**
***CV6-3 Map interpretation**	
Match features on a map to corresponding features in the world	**G P**
***CV6-4 Map analysis**	
Describe maps that can be used to find direction, distance, or position, plan routes, calculate area or volume, or describe shape	**A D**
Describe the differences between azimuths, bearings, and other systems for indicating directions	**A D**
Explain how maps can be used in determining an optimal route or facility selection	**A D**
Explain how maps can be used in terrain analysis (e.g., elevation determination, surface profiles, slope, viewsheds, and gradient)	**A D**
Explain how the types of distortion indicated by projection metadata on a map will affect map measurements	**A D**
Explain the differences between true north, magnetic north, and grid north directional references	**A D**
Compare and contrast the manual measurement of the areas of polygons on a map printed from a GIS with those calculated by the computer and discuss the implications these variations in measurement might have on map use	**A D**
Determine feature counts of point, line, and area features on maps	**A D**
Analyze spatial patterns of selected point, line and area feature arrangements on maps	**A D**
Calculate slope using a topographic map and a DEM	**A D**
Calculate the planimetric and actual road distances between two locations on a topographic map	**A D**
Create a profile of a cross section through a terrain using a topographic map and a digital elevation model (DEM)	**A D**
Measure point-feature movement and point-feature diffusion on maps	**A D**
Plan an orienteering tour of a specific length that traverses slopes of an appropriate steepness and crosses streams in places that can be forded based on a topographic map	**A D**

BODY OF KNOWLEDGE	DACUM
***CV6-5 Evaluation and testing**	
Identify several uses for which a particular map is or is not effective	**GP**
Identify the particular design choices that make a map more or less effective	**GP**
Evaluate the effectiveness of a map for its audience and purpose	**GP**
***CV6-6 Impact of uncertainty**	
Describe a scenario in which possible errors in a map may impact subsequent decision making, such as a land use decision based on a soils map	**GP**
Critique the assumption that maps can or should be "accurate"	**GP**
Evaluate the uncertainty inherent in a map	**GP**
DA. Design Aspects	
DA1 The scope of GI S&T system design	
DA1-1 Using models to represent information and processes	
Assess the data quality needed for a new application to be successful	**C & A D**
Describe the ways in which an existing model faithfully represents reality and the ways in which it does not	**A D**
Recognize the advantages and disadvantages of using models to study and manage the world as opposed to experimenting in the world directly	**A D**
DA1-2 Components of models: data, structures, procedures	
Differentiate the three major parts of a model	**A D**
DA2 Project definition	
DA2-3 Application/user assessment	
Educate potential users on the value of geospatial technology	**T S**
Evaluate the potential for using geospatial technology to improve the efficiency and/or effectiveness of existing activities	**T S**
Classify potential users as casual or professional, early adopters or reluctant users	**T S**
DA3 Resource planning	
DA3-1 Feasibility analysis	
Decide whether geospatial technology should be used for a particular task	**M P**
List the costs and benefits (financial and intangible) of implementing geospatial technology for a particular application or an entire institution	**M P**
Identify major obstacles to the success of a GIS proposal	**M P**
Evaluate possible solutions to the major obstacles that stand in the way of a successful GIS proposal	**M P**

BODY OF KNOWLEDGE	DACUM
DA3-2 Software systems	
Describe the major geospatial software architectures available currently, including desktop GIS, server-based, Internet, and component-based custom applications	**T S**
Describe non-spatial software that can be used in geospatial applications, such as databases, Web services, and programming environments	**T S**
DA3-3 DATA COSTS	
Identify potential sources of data (free or commercial) needed for a particular application or enterprise	**C&A D**
Estimate the cost to collect needed data from primary sources (e.g., remote sensing, GPS)	**C&A D**
Judge the relative merits of obtaining free data, purchasing data, outsourcing data creation, or producing and managing data in-house for a particular application or enterprise	**C&A D**
***DA4 Database design (core unit)**	
***DA4-1 Modeling tools**	
Compare and contrast the relative merits of various textual and graphical tools for data modeling, including E-R diagrams, UML, and XML	**M&M D**
***DA4-2 Conceptual model**	
Define entities and relationships as used in conceptual data models	**M&M D**
***DA4-3 Logical models**	
Define the cardinality of relationships	**M&M D**
Explain the various types of cardinality found in databases	**M&M D**
***DA4-4 Physical models**	
Recognize the constraints and opportunities of a particular choice of software for implementing a logical model	**M&M D**
DA5 Analysis design	
DA6 Application design	
DA6-2 User interfaces	
Design an application-level software/user interface based on user requirements	**T S**
Create user interface components in available development environments	**T S**
DA6-3 Development environments for geospatial applications	
Develop a geospatial application using the most appropriate environment	**T S**
DA6-4 Computer-Aided Software Engineering (CASE) tools	
Evaluate available CASE tools for their appropriateness for a given development task	**T S**

BODY OF KNOWLEDGE	DACUM
Use CASE tools to design geospatial software	**T S**
DA7 System implementation	
DA7-2 Implementation tasks	
Acquire data from primary and secondary sources	**C&A D**
Transfer data from primary and secondary sources into the database	**C&A D**
DM. Data Modeling	
DM1 Basic storage and retrieval structures (14)	
DM1-1 Basic data structures	
Define basic data structure terminology (e.g., records, field, parent/child, nodes, pointers)	**M&M D**
Differentiate among data models, data structures, and file structures	**M&M D**
***DM2 Database management systems (core unit)**	
***DM2-1 Coevolution of DBMS and GIS**	
Differentiate among network, hierarchical and relational database structures, and their uses and limitations for geographic data storage and processing	**M&M D**
***DM2-2 Relational DBMS**	
Define the basic terms used in relational database management systems (e.g., tuple, relation, foreign key, SQL, relational join)	**M&M D**
Create an SQL query that extracts data from related tables	**M&M D**
***DM2-3 Object-oriented DBMS**	
Evaluate the advantages and disadvantages of object-oriented databases compared to relational databases, focusing on representational power, data entry, storage efficiency, and query performance	**M&M D**
***DM2-4 Extensions of the relational model**	
Evaluate the adequacy of contemporary proprietary database schemes to manage geospatial data	**M&M D**
***DM3 Tessellation data models (core unit)**	
***DM3-1 Grid representations**	
Explain how grid representations embody the field-based view	**C F**
***DM3-2 The raster model**	
Define basic terms used in the raster data model (e.g., cell, row, column, value)	**C F**
Explain how the raster data model instantiates a grid representation	**C F**
Interpret the header of a standard raster data file	**C F**

BODY OF KNOWLEDGE	DACUM
***DM3-3 Grid compression methods**	
Differentiate between lossy and lossless compression methods	**C F**
Evaluate the relative merits of grid compression methods for storage	**C F**
***DM3-4 The hexagonal model**	
Illustrate the hexagonal model	**C F**
***DM3-5 The Triangulated Irregular Network (TIN) model**	
Describe the architecture of the TIN model	**C F**
Demonstrate the use of the TIN model for different statistical surfaces (e.g., terrain elevation, population density, disease incidence) in a GIS software application	**C F**
Describe how to generate a unique TIN solution using Delaunay triangulation	**C F**
Construct a TIN manually from a set of spot elevations	**C F**
Delineate a set of break lines that improve the accuracy of a TIN	**C F**
Describe the conditions under which a TIN might be more practical than GRID	**C F**
***DM3-6 Resolution**	
Relate the concept of grid cell resolution to the more general concept of “support” and granularity	**C F**
Illustrate the impact of grid cell resolution on the information that can be portrayed	**C F**
Evaluate the implications of changing grid cell resolution on the results of analytical applications by using GIS software	**C F**
***DM3-7 Hierarchical data models**	
Illustrate the quadtree model	**C F**
Describe the advantages and disadvantages of the quadtree model for geographic database representation & modeling	**C F**
***DM4 Vector and object data models (core unit)**	
***DM4-1 Geometric primitives**	
Identify the three fundamental dimensionalities used to represent points, lines, and areas	**C F**
Describe the data models used to encode coordinates as points, lines, or polygons	**C F**
Critique the assumptions that are made in representing the world as points, lines, and polygons	**C F**
Evaluate the correspondence between geographic phenomena and the shapes used to represent them	**C F**
***DM4-2 The spaghetti model**	
Identify a widely-used example of the spaghetti model (e.g., AutoCAD DWF, ESRI shapefile)	**C F**
Describe how geometric primitives are implemented in the spaghetti model as independent objects without topology	**C F**

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Explain how the spaghetti data model embodies an object-based view of the world	**C F**
Explain the conditions under which the spaghetti model is useful	**C F**
***DM4-3 The topological model**	
Define terms related to topology (e.g., adjacency, connectivity, overlap, intersect, logical consistency)	**C F**
Illustrate a topological relation	**C F**
Explain the advantages and disadvantages of topological data models	**C F**
***DM4-4 Classic vector data models**	
Illustrate the GBF/DIME data model	**C F**
***DM4-5 The network model**	
Define the following terms pertaining to a network: Loops, multiple edges, the degree of a vertex, walk, trail, path, cycle, fundamental cycle	**C F**
Demonstrate how a network is a connected set of edges and vertices	**C F**
List definitions of networks that apply to specific applications or industries	**C F**
***DM4-6 Linear referencing**	
Construct a data structure to contain point or linear geometry for database record events that are referenced by their position along a linear feature	**C F**
Demonstrate how linear referenced locations are often much more intuitive and easy to find in the real world than geographic coordinates	**C F**
Explain how linear referencing allows attributes to be displayed and analyzed that do not correspond precisely with the underlying segmentation of the network features	**C F**
***DM4-7 Object-based spatial databases**	
Evaluate the advantages and disadvantages of the object–based data model compared to the layer-based vector data model (topological or spaghetti)	**C F**
DM5 Modeling 3D, temporal, & uncertain phenomena	
DM5-2 Modeling uncertainty	
Differentiate among modeling uncertainty for entire datasets, for features, and for individual data values	**C F**
DM5-3 Modeling three-dimensional (3D) entities	
Differentiate between 2.5D representations and true 3D models	**C F**
Explain how voxels and stack-unit maps that show the topography of a series of geologic layers might be considered 3D extensions of field and vector representations respectively	**C F**
Explain the difficulties in creating true 3D objects in a vector or raster format	**C F**

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DN. Data Manipulation	
***DN1 Representation transformation (core unit)**	
***DN1-1 Impacts of transformations**	
Compare and contrast the impacts of different conversion approaches, including the effect on spatial components	**M&M D**
***DN1-2 Data model and format conversion**	
Convert a data set from the native format of one GIS product to another	**M&M D**
***DN1-3 Interpolation**	
Differentiate among common interpolation techniques (e.g., nearest neighbor, bilinear, bicubic)	**A D**
Explain how the elevation values in a digital elevation model (DEM) are derived by interpolation from irregular arrays of spot elevations	**A D**
Discuss the pitfalls of using secondary data that has been generated using interpolations (e.g., Level 1 USGS DEMs)	**A D**
Estimate a value between two known values using linear interpolation (e.g., spot elevations, population between census years)	**A D**
***DN1-4 Vector-to-raster and raster-to-vector conversions**	
Explain how the vector/raster/vector conversion process of graphic images and algorithms takes place and how the results are achieved	**M&M D**
Convert vector data to raster format and back using GIS software	**M&M D**
Illustrate the impact of vector/raster/vector conversions on the quality of a dataset	**M&M D**
Create estimated tessellated data sets from point samples or isolines using interpolation operations that are appropriate to the specific situation	**M&M D**
***DN1-5 Raster resampling**	
Discuss the consequences of increasing and decreasing resolution	**A D**
Evaluate methods used by contemporary GIS software to resample raster data on-the-fly during display	**A D**
Select appropriate interpolation techniques to resample particular types of values in raster data (e.g., nominal using nearest neighbor)	**A D**
Resample multiple raster data sets to a single resolution to enable overlay	**A D**
Resample raster data sets (e.g., terrain, satellite imagery) to a resolution appropriate for a map of a particular scale	**A D**
***DN1-6 Coordinate transformations**	
Cite appropriate applications of several coordinate transformation techniques (e.g., affine, similarity, Molodenski, Helmert)	**A D**
Differentiate between polynomial coordinate transformations (including linear) and rubbersheeting	**A D**
Describe the impact of map projection transformation on raster and vector data	**A D**

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***DN2 Generalization and aggregation (core unit)**	
***DN2-1 Scale and generalization**	
Differentiate among the concepts of scale (as in map scale), support, scope, and resolution	**C F**
Determine the mathematical relationships among scale, scope, and resolution, including Töpfer's Radical Law	**C F**
Defend or refute the statement "GIS data are scaleless"	**C F**
Discuss the implications of tradeoff between data detail and data volume	**C F**
Select a level of data detail and accuracy appropriate for a particular application (e.g., viewshed analysis, continental land cover change)	**C F**
***DN2-2 Approaches to point, line, and area generalization**	
Describe the basic forms of generalization used in applications in addition to cartography (e.g., selection, simplification)	**G P**
Discuss the possible effects of generalizing data sets on topological integrity	**G P**
Explain why areal generalization is more difficult than line simplification	**G P**
Explain the pitfalls of using data generalized for small scale display in a large scale application	**G P**
***DN2-3 Classification and transformation of attribute measurement levels**	
Reclassify (group) a nominal attribute domain to fewer, broader classes	**M&M D**
***DN2-4 Aggregation of spatial entities**	
Discuss the conditions that require individual spatial entities to be aggregated (e.g., privacy, security, proprietary interests, data simplification)	**A D**
Demonstrate the relationship between district size (resolution/support) and patterns in aggregate data	**A D**
Summarize the attributes of individuals within regions using spatial joins	**A D**
Demonstrate how changing the geometry of regions changes the data values (e.g., voting patterns before and after redistricting)	**A D**
Discuss the potential pitfalls of using regions to aggregate geographic information (e.g., census data)	**A D**
DN3 Transaction management of geospatial data	
DN3-1 Database change	
Demonstrate the importance of a clean, relatively error free database (together with an appropriate geodetic framework) with the use of GIS software	**M&M D**
Modify spatial and attribute data while ensuring consistency within the database	**M&M D**
Discuss the implication of "long transactions" on database integrity	**M&M D**
Exemplify scenarios in which one would need to perform a number of periodic changes in a real GIS database	**M&M D**

Explain how one would establish the criteria for monitoring the periodic changes in a real GIS database	**M&M D**

GC. Geocomputation

GC1 Emergence of geocomputation

GC1-2 Trends

Describe GI S&T topics that may be addressed by new geocomputation techniques	**C F**
Identify topics and techniques that may be addressed as computer capabilities increase	**C F**

GC2 Computational aspects and neurocomputing

GC3 Cellular Automata (CA) models

GC4 Heuristics

GC5 Genetic algorithms (GA)

GC6 Agent-based models

GC7 Simulation modeling

GC8 Uncertainty

GC9 Fuzzy sets

GD. Geospatial Data

***GD1 Earth geometry (core unit)**

***GD1-1 History of understanding Earth's shape**

Describe how man's understanding of the Earth's shape has evolved throughout history	**C F**
Describe and critique early efforts to measure the Earth's size and shape	**C F**
Explain how technological and mathematical advances have led to more sophisticated knowledge about the Earth's shape	**C F**
Describe the contributions of key individuals (e.g., Eratosthenes, Newton, Picard, Bouguer, LaPlace, La Candamine) to man's understanding of the Earth's shape	**C F**

***GD1-2 Approximating the Earth's shape with geoids**

Explain why gravity varies over the Earth's surface	**C F**
Explain the concept of an equipotential gravity surface (i.e., a geoid)	**C F**

***GD1-3 Approximating the geoid with spheres and ellipsoids**

Distinguish between a geoid, an ellipsoid, a sphere, and the terrain surface	**C F**

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GD2 Land partitioning systems	
GD2-2 Systematic methods	
Explain how townships, ranges, and their sections are delineated in terms of baselines and principal meridians	**C F**
Illustrate how to quarter-off portions of a township and range section	**C F**
***GD3 Georeferencing systems (core unit)**	
***GD3-1 Geographic coordinate system**	
Explain the angular measurements represented by latitude and longitude coordinates	**C F**
Locate on a globe the positions represented by latitude and longitude coordinates	**C F**
***GD3-2 Plane coordinate systems**	
Explain why plane coordinates are sometimes preferable to geographic coordinates	**C F**
Explain what Universal Transverse Mercator (UTM) eastings and northings represent	**C F**
Associate UTM coordinates and zone specifications with corresponding position on a world map or globe	**C F**
Identify the map projection(s) upon which UTM coordinate systems are based, and explain the relationship between the projection(s) and the coordinate system grid	**C F**
Discuss the magnitude and cause of error associated with UTM coordinates	**C F**
Differentiate the characteristics and uses of the UTM coordinate system from the Military Grid Reference System (MGRS) and the World Geographic Reference System (GEOREF)	**C F**
Explain what State Plane Coordinates system (SPC) eastings and northings represent	**C F**
Associate SPC coordinates and zone specifications with corresponding position on a U.S. map or globe	**C F**
Identify the map projection(s) upon which SPC coordinate systems are based, and explain the relationship between the projection(s) and the coordinate system grid	**C F**
Discuss the magnitude and cause of error associated with SPC coordinates	**C F**
Recommend the most appropriate plane coordinate system for applications at different spatial extents and justify the recommendation	**C F**
***GD3-3 Tessellated referencing systems**	
Explain the concept “quadtree”	**C F**
***GD3-4 Linear referencing systems**	
Describe an application in which a linear referencing system is particularly useful	**C F**

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***GD4 Datums (core unit)**	
***GD4-1 Horizontal datums**	
Explain the difference in coordinate specifications for the same position when referenced to NAD 27 and NAD 83	**C F**
***GD4-2 Vertical datums**	
Illustrate the difference between a vertical datum and a geoid	**C F**
***GD5 Map projections (core unit)**	
***GD5-1 Map projection properties**	
Identify and define the four geometric properties of the globe that may be preserved or lost in projected coordinates	**C F**
Explain the concept of a “compromise” projection and for which purposes it is useful	**C F**
Explain the kind of distortion that occurs when raster data are projected	**C F**
Recommend the map projection property that would be useful for various mapping applications, including parcel mapping, route mapping, etc., and justify your recommendations	**C F**
***GD5-2 Map projection classes**	
Explain the concept “developable surface” and “reference globe” as conceptual ways of projecting the Earth’s surface	**C F**
Classify various map projection types by the three main classes of map projections based on developable surfaces	**C F**
***GD5-3 Map projection parameters**	
Define key terms such as "standard line," projection "case," latitude and longitude of origin	**C F**
***GD5-4 Georegistration**	
Differentiate rectification and orthorectification	**C & A D**
Explain the role and selection criteria for “ground control points” (GCPs) in the georegistration of aerial imagery	**C & A D**
Use GIS software to transform a given dataset to a specified coordinate system, projection, and datum	**C & A D**
***GD6 Data quality (core unit)**	
***GD6-1 Geometric accuracy**	
Explain the factors that influence the geometric accuracy of data produced with Global Positioning System (GPS) receivers	**C & A D**
Explain the concept of dilution of precision	**C & A D**
Describe the impact of the concept of dilution of precision on the uncertainty of GPS positioning	**C & A D**
Explain the principle of differential correction in relation to the global positioning system	**C & A D**

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***GD6-2 Thematic accuracy**	
Explain the distinction between thematic accuracy, geometric accuracy, and topological fidelity	**C & A D**
***GD6-3 Resolution**	
Illustrate and explain the distinction between “resolution,” “precision,” and “accuracy”	**C & A D**
Illustrate and explain the distinctions between spatial resolution, thematic resolution, and temporal resolution	**C & A D**
***GD6-4 Precision**	
Explain, in general terms, the difference between single and double precision and impacts on error propagation	**C & A D**
***GD6-5 Feasibility analysis**	
Describe a scenario in which data from a secondary source may pose obstacles to effective and efficient use	**C & A D**
Explain the distinction between primary and secondary data sources in terms of census data, cartographic data, and remotely sensed data	**C & A D**
***GD7 Land surveying and GPS (core unit)**	
***GD7-1 Survey theory and electro-optical methods**	
Apply coordinate geometry to calculate positions in a coordinate system grid based on control point locations and measured angles and distances	**C & A D**
***GD7-2 Land Records**	
Distinguish between GIS, LIS, and CAD/CAM in the context of land records management	**C & A D**
***GD7-3 Global Positioning Systems**	
Explain how GPS receivers calculate coordinate data	**C & A D**
Perform differential correction of GPS data using reference data from a CORS station	**C & A D**
List, define, and rank the sources of error associated with GPS positioning	**C & A D**
Explain “selective availability,” why it was discontinued in 2000, and what alternatives are available to the U.S. Department of Defense	**C & A D**
Discuss the role of GPS in location-based services (LBS)	**C & A D**
Specify the features of a GPS receiver that is able to achieve geometric accuracies on the order of centimeters without post-processing	**C & A D**
Discuss the relationship of GPS to the Global Satellite Navigation System	**C & A D**
Explain the relationship of the U.S. Global Positioning System with comparable systems sponsored by Russia and the European Union and the Global Navigation Satellite System	**C & A D**
Explain the relevance of the concept of trilateration to both GPS positioning and control surveying	**C & A D**

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Distinguish between horizontal and vertical accuracies when using coarse acquisition codes/standard positioning service (C-codes) and precision acquisition codes/precise positioning service (P-codes)	**C & A D**
GD8 Digitizing	
GD8-1 Tablet digitizing	
Digitize and georegister a specified vector feature set to a given geometric accuracy and topological fidelity thresholds using a given map sheet, digitizing tablet, and data entry software	**C & A D**
GD8-2 On-screen digitizing	
Outline a workflow that can be used to train a new employee to update a county road centerlines database using digital aerial imagery and standard GIS editing tools	**C & A D**
GD8-3 Scanning and automated vectorization techniques	
Outline the process of scanning and vectorizing features depicted on a printed map sheet using a given GIS software product, emphasizing issues that require manual intervention	**C & A D**
GD9 Field data collection	
GD9-1 Sample size selection	
Determine the minimum number and distribution of point samples for a given study area and a given statistical test of thematic accuracy	**C & A D**
GD9-2 Spatial sample types	
Design point, transect, and area sampling strategies for given applications	**C & A D**
Differentiate among random, systematic, stratified random, and stratified systematic unaligned sampling strategies	**C & A D**
GD9-4 Field data technologies	
Explain the advantage of real-time kinematic GPS in field data collection	**C & A D**
Describe an application of hand-held computing or personal digital assistants (PDAs) for field data collection	**C & A D**
***GD10 Aerial imaging and photogrammetry (core unit)**	
***GD10-1 Nature of aerial image data**	
Compare and contrast digital and photographic imaging	**A D**
Differentiate oblique and vertical aerial imagery	**A D**
***GD10-2 Platforms and sensors**	
Compare common sensors—including LIDAR, and airborne panchromatic and multispectral cameras and scanners—in terms of spatial resolution, spectral sensitivity, ground coverage, and temporal resolution	**A D**

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***GD10-3 Aerial image interpretation**	
Describe the elements of image interpretation	**A D**
Use photo interpretation keys to interpret features on aerial photographs	**A D**
Using a vertical aerial image, produce a map of land use/land cover classes	**A D**
***GD10-4 Stereoscopy and orthoimagery**	
Evaluate the advantages and disadvantages of photogrammetric methods and LIDAR for production of terrain elevation data	**A D**
***GD10-5 Vector data extraction**	
Describe the source data, instrumentation, and workflow involved in extracting vector data (features and elevations) from analog and digital stereoimagery	**A D**
***GD10-6 Mission planning**	
Plan an aerial imagery mission in response to a given RFP and map of a study area, taking into consideration vertical and horizontal control, atmospheric conditions, time of year, and time of day	**A D**
*** GD11 Satellite and shipboard remote sensing (core unit)**	
***GD11-1 Nature of multispectral image data**	
Draw and explain a diagram that depicts the key bands of the electromagnetic spectrum in relation to the magnitude of electromagnetic energy emitted and/or reflected by the Sun and Earth across the spectrum	**A D**
Describe an application that requires integration of remotely sensed data with GIS and/or GPS data	**A D**
***GD11-2 Platforms and sensors**	
Select the most appropriate remotely sensed data source for a given analytical task, study area, budget, and availability.	**C & A D**
Evaluate the advantages and disadvantages of airborne remote sensing versus satellite remote sensing	**C & A D**
***GD11-3 Algorithms and processing**	
Differentiate supervised classification from unsupervised classification	**C & A D**
Describe an application of hyperspectral image data	**C & A D**
***GD11-4 Ground verification and accuracy assessment**	
Explain how U.S. Geological Survey scientists and contractors assess the accuracy of the National Land Cover Dataset	**C & A D**
***GD11-5 Applications and settings**	
Describe how sea surface temperatures are mapped	**C & A D**
Explain how sea surface temperature maps are used to predict El Niño events	**C & A D**

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***GD12 Metadata, standards, and infrastructures (core unit)**	
***GD12-1 Metadata**	
Define “metadata” in the context of the geospatial data set	**C & A D**
Explain the ways in which metadata increases the value of geospatial data	**C & A D**
Outline the elements of the U.S. geospatial metadata standard	**C & A D**
Interpret the elements of an existing metadata document	**C & A D**
Identify software tools available to support metadata creation	**C & A D**
Explain why metadata production should be integrated into the data production and database development workflows, rather than treated as an ancillary activity	**C & A D**
Use a metadata utility to create a geospatial metadata document for a digital database you created	**C & A D**
Formulate metadata for a graphic output that would be distributed to the general public	**C & A D**
Formulate metadata for a geostatistical analysis that would be released to an experienced audience	**C & A D**
***GD12-2 Content standards**	
Describe the primary focus of the following content standards: FGDC, Dublin Core Metadata Initiative, and ISO 19115	**C & A D**
***GD12-3 Data warehouse**	
Differentiate a data warehouse from a database	**C & A D**
Discuss the appropriate use of a data warehouse versus a database	**C & A D**
Differentiate the retrieval mechanisms of data warehouses and databases	**C & A D**
***GD12-4 Exchange specifications**	
Import data packaged in a standard transfer format to a GIS software package	**M&M D**
Export data from a GIS program to a standard exchange format	**M&M D**
Explain the purpose, history, and status of the Spatial Data Transfer Standard (SDTS)	**M&M D**
***GD12-5 Transport protocols**	
Explain the relevance of transport protocols to GI S&T	**M&M D**
***GD12-6 Spatial data infrastructures**	
Explain the vision, history, and status of the U.S. National Spatial Data Infrastructure	**M&M D**

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GS. GI S&T and Society	
GS1 Legal aspects	
GS1-3 Liability	
Describe strategies for managing liability risk, including disclaimers and data quality standards	**G P**
GS2 Economic aspects	
GS3 Use of geospatial information in the public sector	
GS4 Geospatial information as property	
GS5 Dissemination of geospatial information	
***GS6 Ethical aspects of geospatial information & tech (core unit)**	
***GS6-1 Ethics and geospatial information**	
Describe a scenario in which you would find it necessary to report misconduct by a colleague or friend	**C & A D**
Describe the individuals or groups to which GI S&T professionals have ethical obligations	**C & A D**
***GS6-2 Codes of ethics for geospatial professionals**	
Describe the sanctions imposed by ASPRS and GISCI on individuals whose professional actions violate the Codes of Ethics	**C & A D**
Explain how one or more obligations in the GIS Code of Ethics may conflict with organizations' proprietary interests	**C & A D**
GS7 Critical GIS	
OI. Organizational and Institutional Aspects	
OI1 Origins of GI S&T	
O2 Managing the GI system operations and infrastructure	
OI3 Organizational structures and procedures	
OI4 GI S&T workforce themes	
***OI5 Institutional and inter-institutional aspects (core unit)**	
***OI5-1 Spatial data infrastructures**	
Explain how clearing houses, metadata, and standards can help facilitate spatial data sharing	**C & A D**
***OI5-2 Adoption of standards**	
Identify standards that are used in GI S&T	**C & A D**
Explain how a business case analysis can be used to justify the expense of implementing consensus-based standards	**C & A D**

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***OI5-3 Technology transfer**	
Explain how an understanding of use of current and proposed technology in other organizations can aid in implementing a GI system	**C & A D**
***OI5-4 Spatial data sharing among organizations**	
Describe the rationale for and against sharing data among organizations	**C & A D**
Describe methods used by organizations to facilitate data sharing	**C & A D**
Describe the barriers to information sharing	**C & A D**
***OI5-5 Openness**	
Differentiate “open standards,” “open source,” and “open systems”	**C & A D**
Discuss the advantages and disadvantages of adopting open systems in the context of a local government	**C & A D**
***OI5-6 Balancing data access, security, and privacy**	
Exemplify areas where post-9/11 changes in policies have restricted or expanded data access	**C & A D**
***OI5-7 Implications of distributed GI S&T**	
Describe the advantages and disadvantages to an organization in using GIS portal information from other organizations	**C & A D**
***OI5-8 Inter-organizational and vendor GI systems (software, hardware and systems)**	
Discuss the roles traditionally performed by software vendors in developing professionals in GI S&T	**C & A D**
Discuss the history of major geospatial-centric companies, including software, hardware, and data vendors	**C & A D**
***OI6 Coordinating organizations (national/international) (core unit)**	
***OI6-1 Federal agencies and national and international organizations and programs**	
Describe the data programs provided by organizations such as The National Map, GeoSpatial One Stop, and National Integrated Land System	**C & A D**
***OI6-2 State and regional coordinating bodies**	
Explain the functions, mission, history, constituencies, and activities of your state GIS Council and related formal and informal bodies	**C & A D**
***OI6-3 Professional organizations**	
Compare and contrast the missions, histories, constituencies, and activities of professional organizations including Association of American Geographers (AAG), America Society for Photogrammetry and Remote Sensing (ASPRS), Geospatial Information and Technology Association (GITA), Management Association for Private Photogrammetric Surveyors (MAPPS), and Urban and Regional Information Systems Association (URISA)	**AT**
***OI6-4 Publications**	
Describe the leading academic journals serving the GI S&T community	**AT**

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***OI6-5 The geospatial community**	
Discuss the value or effect of participation in societies, conferences, and informal communities to entities managing enterprise GI systems	**AT**
***OI6-6 The geospatial industry**	
Describe the U.S. geospatial industry including vendors, software, hardware and data	**AT**
Describe three applications of geospatial technology for different workforce domains (e.g., first responders, forestry, water resource management, facilities management)	**AT**

Reference List

DACUM Handbook; Center for Education and Training for Employment, College of Education, Ohio State University, 2nd Edition, 1997

Geographic Information Science & Technology, Body of Knowledge; University Consortium for Geographic Information Science; First Edition, Association of American Geographers, 2006

SCID Handbook, Systematic Curriculum and Instructional Development; Center for Education and Training for Employment, College of Education, Ohio State University, 5th Edition, 2003