New AP® Course Proposal

Geographic Information Science and Technology

AAG
AMERICAN ASSOCIATION of GEOGRAPHERS

COURSE DESCRIPTION

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GEOGRAPHIC INFORMATION SCIENCE AND TECHNOLOGY

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CONTEXT OF GIS&T IN HIGHER EDUCATION

Coursework in Geographic Information Science and Technology (GIS&T) is offered in undergraduate and graduate curricula across a wide range of university programs. GIS&T is prominent in academic geography programs, but credit for GIS&T coursework also counts toward majors in urban planning, landscape architecture, environmental science, engineering, and many other fields (Wikle & Fagin, 2014).

One of the most useful curriculum guides for GIS&T in higher education is the *Geographic Information Science and Technology Body of Knowledge* (GIS&T BoK). This book is based on 10 knowledge areas that characterize the broader domain of the GIS&T discipline. Each knowledge area contains several fine-grained topical units representing concepts, methodologies, operations, and technical aspects of the parent knowledge area.

Originally published in 2006, the GIS&T BoK is the definitive inventory of the conceptual foundations and core knowledge areas of geographic information science (DiBiase et al. 2006). Building on the Model Curricula for GIS&T education published in the early 1990s by the National Center for Geographic Information and Analysis (NCGIA) (Kemp & Goodchild, 1991), the GIS&T BoK was developed by over 70 GIS scholars and practitioners with support from the University Consortium of Geographic Information Science, Esri, and the American Association of Geographers. It is also common for academic GIS&T programs to align coursework with the U.S. Department of Labor's Geospatial Technology Competency Model (GTCM), which provides a comprehensive account of the professional skills required for employment in the geospatial technology industry (DiBiase et al., 2010).

Another driver of GIS&T in higher education is the growth in demand for certification as a GIS Professional (GISP). Though not mandatory for employment purposes, GISP is an increasingly sought after credential. In addition to higher education coursework, GISP certification requirements often include internships, participation in professional and industry conferences, and other related educational experiences.

Methodology

The proposal committee used three sources to compile a database of 451 undergraduate GIS&T programs in the U.S.: the *AAG Guide to Geography Programs in the Americas,* the *AAG Directory of Online Geography Programs*, and the GeoTech Center's database of GIS&T programs. Key institutional characteristics of these 451 GIS&T programs include:

- 101 of the GIS&T programs are located in universities represented in the College Board's Top 200 ranking of institutions receiving the most AP scores.
- 270 colleges and universities offer an undergraduate GIS&T certificate program and 128 offer a master's-level GIS&T certificate program. These certificate programs usually require students to complete a sequence of several courses.
- GIS&T courses are offered in the curriculum for an Associate degree at 136 institutions and for a Bachelor's degree at 256 institutions.
- "Geographic Information Systems" is the most commonly used nomenclature for the introductory GIS&T course.

The proposal committee decided to base the AP GIS&T course description on a content analysis of introductory GIS&T course syllabi and their associated course catalog descriptions. The committee prepared the database for this analysis as follows.

First, the committee organized the 451 undergraduate GIS&T programs into four Census-defined regions (Midwest, Northeast, South, and West). Next, 200 programs were randomly selected for potential inclusion in the analysis. Purposive sampling was then used to identify programs that made both their course syllabi and course catalog descriptions accessible online. Additional considerations in selecting which programs to analyze included maintaining a proportional balance of the degree program types and academic disciplines represented in the larger database. This process ultimately produced a sample of course syllabi and course catalog descriptions from 30 programs for the content analysis. Table 1 presents the geographic, institutional, and disciplinary characteristics of the program sample (n=30) in relation to the overall GIS&T undergraduate program database (N=451).

Table 1. *Geographic, Institutional, and Disciplinary Contexts of Undergraduate GIS&T Education.*

	Program Sample (n=30)	**Program Database (N=451)**
Geographic Context of Undergraduate GIS&T Programs		
Northeast	4 (13%)	66 (15%)
Midwest	10 (33%)	145 (32%)
South	7 (24%)	126 (28%)
West	9 (30%)	114 (25%)
Institutional Context of Undergraduate GIS&T Programs		
Number of 4-year Bachelor’s degree programs	21 (70%)	284 (63%)
Number of 2-year Associate degree programs	9 (30%)	167 (37%)
Disciplinary Context of Introductory GIS&T Course Offerings		
Geography department or hybrid department with a geography or geospatial information science curriculum	25 (83%)	370 (82%)
Other (e.g., architecture, biology, civil engineering, computer science, drafting & design, economics, geoscience, forestry & natural resources, geology, political science, and urban affairs & planning).	5 (17%)	81 (18%)

Recommended Course Topics for AP GIS&T

The proposal committee used the GIS&T BoK taxonomy to code and classify the course descriptions, course topics, and learning objectives in the sample of 30 introductory GIS&T course syllabi and course catalog descriptions. The committee's analysis identified 16 topical units that are generally representative of the content of introductory GIS&T courses. These topics fall under six GIS&T knowledge areas: 1) Analytical Methods, 2) Conceptual Foundations, 3) Cartography and Visualization, 4) Data Modeling, 5) Geospatial Data, and 6) GIS&T and Society. To be considered for inclusion, a topic must have appeared in the syllabi of at least 10 programs.

It should be noted that many introductory GIS&T courses also include a discussion of workforce issues and career opportunities in the geospatial technology industry. The AAG has developed an extensive collection of educational resources and outreach materials related to GIS&T careers that could enhance the teaching of the AP GIS&T course.

Table 2 presents the committee's recommended syllabus of knowledge areas and topical units for the AP GIS&T course. Please refer to the appended GIS&T Body of Knowledge publication for the full detailed descriptions of the knowledge, skills, and abilities related to each topic.

Table 2. *Proposed Topic Outline for the AP GIS&T Course Syllabus. Descriptions of core knowledge areas and topical units are based on the GIS&T Body of Knowledge (DiBiase et al., 2006).*

I. Analytical Methods: *This knowledge area encompasses a wide variety of operations whose objective is to derive analytical results from geospatial data. Data analysis seeks to understand both first-order (environmental) effects and second-order (interaction) effects.*

Unit A. Basic Analytical Operations. A small set of analytical operations commonly applied to a broad range of problems. Their inclusion in software products is often used to determine if that product is a "true" GIS.

- Buffers
- Overlay
- Neighborhoods
- Map algebra

Unit B. Basic Analytical Methods. Building on the basic geometric measures and analytical operations found in most GIS products, a broad range of additional analytical methods form the fundamental GIS toolkit.

- Point pattern analysis
- Kernels and density estimation
- Spatial cluster analysis
- Spatial interaction
- Analyzing multidimensional attributes
- Cartographic modeling
- Multi-criteria evaluation
- Spatial process models

II. Conceptual Foundations: *The GIS&T perspective is grounded in spatial thinking. Wise design and use of geospatial technologies requires an understanding of the nature of geographic information and the principles of geography.*

Unit A. Domains of Geographic Information. Geographic phenomena, geographic information, and geographic tasks are described in terms of space, time, and properties. Different theories exist as to the nature and formal representation of these aspects, including space-like dimensions, sets, and phenomenology. Information in each of these three "aspects" is measured and reported with respect to one of several frames of reference or domains, including both absolute and relative approaches. Early frameworks such as those of Berry (1964) and Sinton (1978) were influential in setting forth the importance of space, time, and theme in GIS.

- Space
- Time
- Relationships between space and time
- Properties

Unit B. Elements of Geographic Information. The concepts below form the basic elements of common human conceptions of geographic phenomena. Concepts from many units in this knowledge area have been synthesized to create general conceptual models of geographic information.

- Discrete entities
- Events and processes
- Fields in space and time
- Integrated models

III. Cartography and Visualization: *Cartography and visualization primarily relate to the visual display of geographic information. This knowledge area addresses the complex issues involved in effective visual thinking and communication of geospatial data and of the results of geospatial analysis. This knowledge area reflects much of the domain of cartography and visualization, although some concepts and skills in these areas can be found in other knowledge areas. For example, the process of visualization encompasses aspects of analysis as well as cartography.*

Unit A. Data Considerations. This unit relates to data compilation and management for cartography and visualization. Certain data manipulations can and should be made prior to symbolization and labeling, although they are not made without consideration of the symbolization and labeling that will be applied. Symbolization and labeling requirements will shape the way the data used in the displays are selected, generalized, classified, projected, and otherwise manipulated. In this unit, the considerations for data selection, subsequent abstraction for cartographic and visualization purposes, and manipulations for display are considered.

- Source materials for mapping
- Data abstraction: classification, selection, and generalization
- Projections as a map design issue

Unit B. Principles of Map Design. This topic covers basic design principles that are used in mapping and visualization, as well as cartographic design principles specific to the display of geographic data. Both page layout design and data display are addressed.

- Map design fundamentals
- Basic concepts of symbolization
- Color for cartography and visualization
- Typography for cartography and visualization

Unit C. Map Use and Evaluation. This unit addresses how people use maps or visualizations for map reading, analysis, discovery, and interpretation. Map reading is the translation of the graphic or other representation of features into a mental image of the environment. It involves the identification of map symbols and the interpretation of the symbology to understand the geographic phenomena. Map analysis allows the reader to analyze and understand the spatial structure of and relationships among features on a map. Visualizations often allow discovery of unexpected patterns and associations in data sets. Interpretation allows the reader to seek explanations for unusual or interesting patterns on maps. The reader can either look at one map and seek explanations for the patterns observed or look at several maps and seek understanding of the variations (perhaps through time) between the maps. Evaluation leads to better understanding of the user experience with the map or visualization. This unit also examines the impact of uncertainty in the data on the map use and evaluation of the use of the displayed data by the map reader.

- The power of maps
- Map reading
- Map interpretation
- Map analysis
- Evaluation and testing
- Impact of uncertainty

IV. Data Modeling: *This knowledge area deals with representation of formalized spatial and spatio-temporal reality through data models and the translation of these data models into data structures that are capable of being implemented within a computational environment (i.e., within a GIS). Data models provide the means for formalizing the spatio-temporal conceptualizations that will be translated into computational data structures. Examples of spatial data model types are discrete (object-based), continuous (location-based), dynamic, and probabilistic. Database management systems and their application to geospatial data are included within this knowledge area. Data structures represent the operational implementation of data models within a computational environment.*

Unit A. Database Management Systems. This unit considers the use of database management systems (DBMS) in geographic contexts and the evolution of modern database design technologies to better handle geographic data in its various forms.

- Coevolution of DBMS and GIS
- Relational DBMS
- Object-oriented DBMS
- Extensions of the relational model

Unit B. Tessellation Data Models. “Tessellation” partitions a continuous surface into a set of non-overlapping polygons that cover the surface without gaps. Tessellation data models represent continuous surfaces with sets of data values that correspond to partitions.

- Grid representations
- The raster model
- Grid compression methods
- The hexagonal model
- The Triangulated Irregular Network (TIN) model
- Resolution
- Hierarchical data models

Unit C. Vector and Object Data Models. Vector data models represent discrete entities by delineating points, lines, boundaries, and nodes as sets of coordinate values with associated attributes. This unit also examines recent methods and strategies for representing information in a more human-centered and natural way that goes beyond traditional vector models for representing an object-based view.

- Geometric primitives
- The spaghetti model
- The topological model
- Classic vector data models
- The network model
- Linear referencing
- Object-based spatial databases

V. Geospatial Data. *Geospatial data represent measurements of the locations and attributes of phenomena at or near Earth's surface. Information is data made meaningful in the context of a question or problem. Information is rendered from data through analytical methods. Information quality and value depends to a large extent on the quality and currency of data (though historical data are valuable for many applications). Geospatial data may have spatial, temporal, and attribute (descriptive) components, as well as associated metadata. Data may be acquired from primary or secondary data sources. Examples of primary data sources include surveying, remote sensing (including aerial and satellite imaging), the global positioning system (GPS), work logs (e.g., police traffic crash reports), environmental monitoring stations, and field surveys. Secondary geospatial or geospatial-temporal data can be acquired by digitizing and scanning analog maps, as well as from other sources, such as governmental agencies.*

Unit A. Georeferencing Systems. Geospatial referencing systems provide unique codes for every location on the surface of the Earth (or other celestial bodies). These codes are used to measure distances, areas, and volumes; to navigate; and to predict how and where phenomena on the Earth's surface may move, spread, or contract. Point-based, vector coordinate systems specify locations in relation to the origins of planar or spherical grids. Tessellated referencing systems specify locations hierarchically, as sequences of numbers that represent smaller and smaller subdivisions of two- or three-dimensional surfaces that approximate the Earth's shape.

- Geographic coordinate system
- Plane coordinate systems
- Tessellated referencing systems
- Linear referencing systems

Unit B. Map Projections. Map projections are plane coordinate grids that have been transformed from spherical coordinate grids using mathematical formulae. Inverse projections transform plane coordinates to geographic coordinates. Plane coordinate systems are thus based upon map projections. Because transformation from a spherical grid to a flat grid inevitably distorts the geometry of the grid, and because different projection formulae produce different distortion patterns, knowledgeable selection of appropriate map projections for particular uses is critical.

- Map projection properties
- Map projection classes
- Map projection parameters
- Georegistration

Unit C. Data Quality. The ultimate standard of quality is the degree to which a geospatial data set is fit for use in a particular application. That standard varies from one application to another. In general, however, the key criteria are how much uncertainty is present in a data set and how much uncertainty is acceptable. Judgments about fitness for use may be more difficult when data are acquired from secondary rather than primary sources. Aspects of data quality include accuracy, resolution, and precision.

- Geometric accuracy
- Thematic accuracy
- Resolution
- Precision
- Primary and secondary sources

Unit D. Satellite and Shipboard Remote Sensing. Satellite-based sensors enable frequent mapping and analysis of very large areas. Many sensing instruments are able to measure electromagnetic energy at multiple wavelengths, including those beyond the visible band. Satellite remote sensing is a key source for regional- and global-scale land use and land cover mapping, environmental resource management, mineral exploration, and global change research. Shipboard sensors employ acoustic energy to determine seafloor depth or to create imagery of the seafloor or water column. The topics included in this unit do not comprise an exhaustive treatment of remote sensing, but they are aspects of the field about which all geospatial professionals should be knowledgeable.

- Nature of multispectral image data
- Platforms and sensors
- Algorithms and processing
- Ground verification and accuracy assessment
- Applications and settings

Unit E. Metadata, Standards, and Infrastructures. Governments and businesses alike invest large sums to produce the geospatial data on which much of their operations depend. To maximize returns on these investments, organizations seek to minimize redundancies and facilitate reuse of data resources. One way to achieve efficiencies is to standardize the methods by which organizations encode, structure, document, and exchange geospatial data.

- Metadata
- Content standards
- Data warehouse
- Exchange specifications
- Transport protocols
- Spatial data infrastructures

VI. GIS&T and Society: *Geographic Information Science and Technology exists to serve society, but it is not a panacea. Societal issues arise from conflicting proprietary and public interests, around privacy concerns and who benefits from the collection and use of geospatial information. The need to choose among conflicting interests sometimes poses ethical dilemmas for GIS&T professionals.*

Unit A. Ethical aspects of geospatial information and technology. Ethics provide frameworks that help individuals and organizations make decisions when confronted with choices that have moral implications. Most professional organizations develop codes of ethics to help their members do the right thing, preserve their reputation in the community, and help their members develop as a community.

- Ethics and geospatial information
- Codes of ethics for geospatial professionals
- Ethical critiques

Course Prerequisites

Introductory undergraduate AP GIS&T courses do not typically have prerequisites. Nearly 75% of the syllabi analyzed for this proposal do not specify a prerequisite. At institutions where a prerequisite course is recommended, it is usually a course in basic mathematics.

Description of the Sequent Course

The names of sequent courses in GIS&T are more varied than the introductory course. Commonly used phrases in sequent AP GIS&T courses include “Geographic Information Systems II”, “Remote Sensing”, “Spatial Analysis and Modeling”, and “GIS Programming”.

Students who continue coursework in GIS&T build upon the foundational knowledge of the introductory course. This happens in two ways:

(1) The sequent course typically introduces more advanced topics within the six knowledge areas that appear in the proposed AP GIS&T syllabus. Examples of the topical coverage in intermediate-level AP GIS&T courses include:

A. Analytical Methods

- Spatial statistics
- Geostatistics
- Spatial regression and econometrics
- Data mining
- Network analysis

B. Conceptual Foundations

- Philosophical foundations
- Cognitive and social foundations
- Imperfections in geographic information

C. Cartography and Visualization

- History and trends
- Graphic representation techniques
- Map production

D. Data Modeling

- Storage and retrieval structures
- Modeling 3D, temporal, and uncertain phenomena

E. Geospatial Data

- Land partitioning data
- Land surveying and GPS
- Field data collection

F. GIS&T and Society

- Critical GIS
- Dissemination of Geospatial Information
- Legal Aspects
- Economic Aspects

(2) The sequent course often delves into the other four knowledge areas identified in the GIS&T BoK publication. Examples of these additional knowledge areas and topical units include:

A. Design Aspects

- Scope of GIS&T system design
- Project definition
- Resource planning
- Database design
- Analysis design
- Application design
- System implementation

B. Data Manipulation

- Generalization and aggregation
- Transaction management of geospatial data

C. Geocomputation

- Emergence of geocomputation
- Computational aspects and neurocomputing
- Cellular Automatic models
- Heuristics
- Simulation modeling
- Fuzzy sets

D. Organizational and Institutional Aspects

- Managing GIS operations and infrastructure
- Organizational structures and procedures
- Workforce themes
- Coordinating organizations (national and international)

Recommended AP Course Classification

The proposal committee recommends classifying the AP GIS&T course as a STEM offering in the AP program (potentially as an addition to the current Math and Computer Science AP offerings).

GIS&T is closely aligned with national STEM education and workforce imperatives. Although there is no single federal list or definition of "STEM" disciplines, the U.S. National Science Foundation has always included geography among STEM fields, and the Department of Homeland Security had included various geographic technology specialties as STEM disciplines for purposes of various visa programs.

Another reason to classify AP GIS&T as a STEM course is to complement AP Human Geography (APHG), which is a social science offering. Students taking AP GIS&T will likely become inspired to gain additional geographical knowledge and perspectives provided by APHG. Similarly, students attracted to APHG will likely see the advantages of taking a complementary course that teaches modern applications of geographic information science and geospatial technologies. The potential synergy with APHG provides yet another rationale for establishing an AP GIS&T course.

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