

# Minds On GIS: Encouraging Spatial Thinking in an Introductory GIS Lab

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# Typical GIS Labs



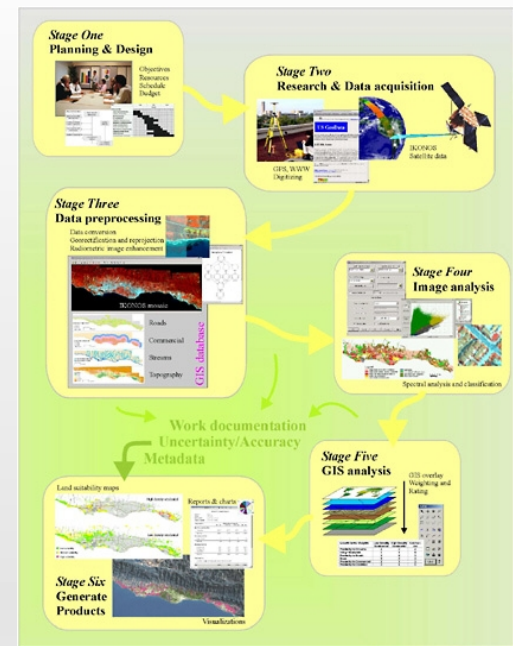
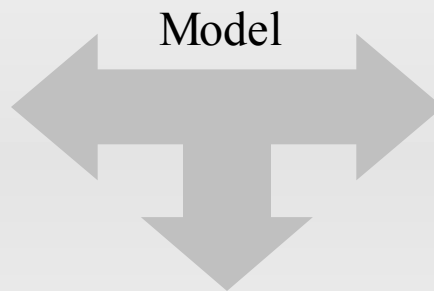
Match the teaching style  
with the learning style

Cookbook labs:  
Behavioral form of  
teaching/learning

Restructure labs to  
emphasize a more  
constructivist bent

Model

Geographic Information Science & Technology Body of Knowledge	
<small>Edited by David Edrington, 2010 and updated, 2016. Authors: Karim Elmqvist, David Foray, Lutz Hartmann, Michael Hurn, and Johannes Strobel UNIVERSITY CONSORTIUM FOR GEOGRAPHIC INFORMATION SCIENCE</small>	
<b>Analytical Methods</b> <b>AM1 Academic and analytical origins</b> 1.1 Research traditions 1.2 Interdisciplinary approaches <b>AM2 Query operations and query languages</b> 2.1 Query languages 2.2 Query processing <b>AM3 Geographic reasoning</b> 3.1 Reasoning about spatial relationships 3.2 Reasoning about spatial constraints <b>AM4 Basic analytical operations</b> 4.1 Selection 4.2 Aggregation 4.3 Joining <b>AM5 Basic analytical methods</b> 5.1 Point pattern analysis 5.2 Line pattern analysis 5.3 Area pattern analysis 5.4 Network analysis 5.5 Surface analysis <b>AM6 Analysis of surfaces</b> 6.1 Descriptive statistics 6.2 Inferential statistics 6.3 Regression analysis	<b>Cartography and Visualization</b> <b>CV1 History and trends</b> 1.1 History of cartography 1.2 Modern cartography <b>CV2 Visualization techniques</b> 2.1 Visual encoding 2.2 Visual design 2.3 Visual communication <b>CV3 Principles of map design</b> 3.1 Map design process 3.2 Map design principles <b>CV4 Map production</b> 4.1 Map production process 4.2 Map production technologies <b>CV5 Map use and evaluation</b> 5.1 Map use 5.2 Map evaluation
<b>Conceptual Foundations</b> <b>CF1 Philosophical foundations</b> 1.1 Foundations of GIS 1.2 Foundations of GIScience <b>CF2 Cognitive and social foundations</b> 2.1 Cognitive foundations 2.2 Social foundations <b>CF3 Domains of geographic information</b> 3.1 Urban 3.2 Environmental 3.3 Cultural	<b>Design Aspects</b> <b>DA1 The scope of GIS/T</b> 1.1 GIS/T scope 1.2 GIS/T applications <b>DA2 Project definition</b> 2.1 Project definition 2.2 Project requirements <b>DA3 Resource planning</b> 3.1 Resource planning 3.2 Resource allocation <b>DA4 Database design</b> 4.1 Database design 4.2 Database implementation <b>DA5 Analysis design</b> 5.1 Analysis design 5.2 Analysis implementation <b>DA6 Application design</b> 6.1 Application design 6.2 Application implementation <b>DA7 System implementation</b> 7.1 System implementation 7.2 System evaluation
<b>Data Modeling</b> <b>DM1 Basic storage and retrieval structures</b> 1.1 Basic storage and retrieval structures 1.2 Basic storage and retrieval structures <b>DM2 Database management systems</b> 2.1 Database management systems 2.2 Database management systems <b>DM3 Modeling 2D, 3D, uncertain, and temporal phenomena</b> 3.1 Modeling 2D, 3D, uncertain, and temporal phenomena 3.2 Modeling 2D, 3D, uncertain, and temporal phenomena	<b>DM4 Vector and object data models</b> 4.1 Vector and object data models 4.2 Vector and object data models <b>DM5 Modeling 2D, 3D, uncertain, and temporal phenomena</b> 5.1 Modeling 2D, 3D, uncertain, and temporal phenomena 5.2 Modeling 2D, 3D, uncertain, and temporal phenomena



Question - > Question  
 Prediction - > Reflection  
 Prediction - > Revision - > Decision

# Geographic Information Science & Technology Body of Knowledge

Edited by Frank Ertugrul, Michael DeGloria, Ann Johnson, Karen Knapp, Ann Taylor Lamb, Brandon Pierce, and Elizabeth Young

UNIVERSITY CONSORTIUM FOR GEOGRAPHIC INFORMATION SCIENCE

## Analytical Methods

### AM1 Academic and analytical origins

- 1-1 Academic foundations
- 1-2 Analytical approaches

### AM2 Query operations and query languages

- 2-1 Query theory
- 2-2 Standard Query Language (SQL) and database systems
- 2-3 Spatial queries

### AM3 Geometric measures

- 3-1 Distance and length
- 3-2 Area/volume
- 3-3 Slope
- 3-4 Area
- 3-5 Perimeter and distance decay
- 3-6 Adjacency and connectivity

### AM4 Basic analytical operations

- 4-1 Buffering
- 4-2 Overlay
- 4-3 Neighborhoods
- 4-4 Map algebra

### AM5 Basic analytical methods

- 5-1 Point pattern analysis
- 5-2 Distance and density estimation
- 5-3 Spatial cluster analysis
- 5-4 Spatial interaction
- 5-5 Analyzing multi-dimensional attributes
- 5-6 Geographic modeling
- 5-7 Multivariate analysis
- 5-8 Spatial process models

### AM6 Analysis of surfaces

- 6-1 Calculating surface derivatives
- 6-2 Interpretation of surfaces
- 6-3 Surface features
- 6-4 Topography
- 6-5 Slope surfaces

### AM7 Spatial statistics

- 7-1 Regional statistics
- 7-2 Multivariate processes
- 7-3 The spatial weights matrix
- 7-4 Global measures of spatial association
- 7-5 Local measures of spatial association
- 7-6 Outliers
- 7-7 Bayesian methods

### AM8 Geostatistics

- 8-1 Spatial sampling for statistical analysis
- 8-2 Structure of geostatistical analysis
- 8-3 Data management modeling
- 8-4 Kriging and co-kriging
- 8-5 Spatial models

### AM9 Spatial regression and econometrics

- 9-1 Interpretation of spatial econometrics
- 9-2 Spatial econometric models
- 9-3 Spatial modeling
- 9-4 Spatial regression and diagnosticity
- 9-5 Weighted Least Squares (WLS)

### AM10 Data Mining

- 10-1 Definition of large spatial datasets
- 10-2 Data mining approaches
- 10-3 Knowledge discovery
- 10-4 Feature recognition and modeling

### AM11 Network analysis

- 11-1 Network definition
- 11-2 Graph-theoretic (topological) measures
- 11-3 Network shortest paths
- 11-4 Flow modeling
- 11-5 The Traveling Salesman Problem
- 11-6 Other classic network problems
- 11-7 Accessibility modeling

### AM12 Optimization and location-allocation modeling

- 12-1 Operations research modeling and systems modeling overview
- 12-2 Linear programming
- 12-3 Integer programming
- 12-4 Location-allocation modeling and

## Conceptual Foundations

### CF1 Philosophical foundations

- 1-1 Philosophy and ontology
- 1-2 Epistemology
- 1-3 Methodological perspectives

### CF2 Cognitive and social foundations

- 2-1 Theoretical foundations of geographic phenomena
- 2-2 From a map to GIS
- 2-3 Geography as a Discipline (GI-D)
- 2-4 From GIS to GIScience
- 2-5 Cognitive and social geographic information science
- 2-6 Cultural software
- 2-7 Software science

### CF3 Domains of geographic information

- 3-1 Space
- 3-2 Time
- 3-3 Knowledge between space and time
- 3-4 Properties

### CF4 Elements of geographic information

- 4-1 Objects within
- 4-2 Events and processes
- 4-3 Relations among data
- 4-4 Organizational models

### CF5 Relationships

- 5-1 Categories
- 5-2 Hierarchical/abstract relationships
- 5-3 Dimensional relationships: things, phenomena
- 5-4 Topological relationships
- 5-5 Dimensional relationships: distance and direction
- 5-6 Spatial distributions
- 5-7 Regions
- 5-8 Spatial integration

### CF6 Imperfections in geographic information

- 6-1 Systems
- 6-2 Methodological models of representation
- 6-3 Proxy sets and proxy sets
- 6-4 Spatial model quality
- 6-5 Methodological models of uncertainty
- 6-6 Uncertainty and distance

## Cartography and Visualization

### CV1 History and trends

- 1-1 History of cartography
- 1-2 Technological innovations

### CV2 Data visualization

- 2-1 Visual materials for mapping
- 2-2 Visualization: visualization, cartography, and urban systems
- 2-3 Perspective as a visual design device

### CV3 Principles of map design

- 3-1 Map design fundamentals
- 3-2 Data visualization of spatialization
- 3-3 Visual design and communication
- 3-4 Designing for cartography and visualization

### CV4 Map production

- 4-1 Cartographic design
- 4-2 Map production
- 4-3 Map reproduction

### CV5 Map use and evaluation

- 5-1 User-centered design
- 5-2 Map reading
- 5-3 Map interpretation
- 5-4 Evaluation and testing
- 5-5 Impact of usability

## Design Aspects

### DA1 The scope of GIS&T system design

- 1-1 Design methods to represent information
- 1-2 Representability of remote data, attributes, metadata
- 1-3 Representability of GIS&T applications
- 1-4 The scope of GIS&T design
- 1-5 The process of GIS&T design

### DA2 Project definition

- 2-1 Problem definition
- 2-2 Planning for design
- 2-3 Application user requirements
- 2-4 Requirements analysis
- 2-5 Data, policies, and related needs

### DA3 Resource planning

- 3-1 Feasibility analysis
- 3-2 Software options
- 3-3 Data costs
- 3-4 Labor and management
- 3-5 System, facilities and equipment
- 3-6 Staffing

### DA4 Database design

- 4-1 Modeling needs
- 4-2 Development alternatives for geographic applications
- 4-3 Object-oriented Software Engineering (OOSE) theory

### DA5 Application design

- 5-1 User interface
- 5-2 Development alternatives for geographic applications
- 5-3 User-centered Software Engineering (UCSE) theory

### DA6 System implementation

- 6-1 Design implementation
- 6-2 User requirements
- 6-3 System log format

### DA7 Database management systems

- 7-1 Overview of GIS&T and GIS
- 7-2 Database DBMS
- 7-3 Data model and GIS
- 7-4 Structure of the relational model

### DA8 Vector and object data models

- 8-1 Relational model
- 8-2 Topological model
- 8-3 Object-oriented data models
- 8-4 Layered model
- 8-5 Layered model
- 8-6 Object-oriented spatial database

### DA9 Modeling 3D, uncertain, and temporal phenomena

- 9-1 Systemic view (SV)
- 9-2 Modeling uncertainty
- 9-3 Modeling three-dimensional entities

### DA10 Transition data models

- 10-1 Overview
- 10-2 The raster model
- 10-3 Vector representation methods
- 10-4 The vector model
- 10-5 The Triangular Irregular Network (TIN) model
- 10-6 Data models
- 10-7 Hierarchical data models

*“The Body of Knowledge is a resource for specifying course content, for designing educational activities, and for assessing courses’ effectiveness in achieving intended outcomes.” – BOK*

10 K knowledge Areas

73 Units

330+ Topics

<http://www.aag.org/bok/>

CF. Conceptual Foundations  
CF1 Philosophical foundations  
CF2 Domains of geographic information  
CF3 Cognitive foundations  
CF4 Geographic foundations  
CF5 Social foundations  
CF6 Theoretical models  
CF7 Imperfections in geographic information

CV. Cartography and Visualization  
CV1 History and trends  
CV2 Data considerations for cartography and visualization  
CV3 Principles of map design  
CV4 Graphic representation techniques  
CV5 Map production  
CV6 Map use and evaluation

DA. Data Analysis  
DA1 Academic foundations of geospatial data analysis  
DA2 Query operations and query languages  
DA3 Geometric operations on spatial objects  
DA4 Modeling relationships and patterns  
DA5 Analysis of surfaces  
DA6 Spatial statistics  
DA7 Geostatistics  
DA8 Spatial econometrics  
DA9 Data mining  
DA10 Network analysis  
DA11 Operations research

DE. Design Aspects  
DE1 Applications as models  
DE2 Project definition  
DE3 Resource planning  
DE4 Database design  
DE5 Analytic model design  
DE6 Application design  
DE7 System implementation

DM. Data Modeling  
DM1 Basic storage and retrieval structures  
DM2 DBMS and the relational model  
DM3 Tessellation data models  
DM4 Vector data models  
DM5 Multiple scale representation/models  
DM6 Object (oriented) and object based models  
DM7 Temporal representation/models  
DM8 Metadata  
DM9 Data exchange and operability

DN. Data Manipulation  
DN1 Data format conversion  
DN2 Generalization and aggregation  
DN3 Transaction management of geospatial data

GC. Geocomputation  
GC1 History and trends in geocomputation  
GC2 Uncertainty  
GC3 Computational aspects and neurocomputing  
GC4 Fuzzy sets  
GC5 Cellular automata (CA) models  
GC6 Heuristics  
GC7 Genetic algorithms  
GC8 Agent-based models  
GC9 Activity analysis

GD. Geospatial Data  
GD1 Earth geometry  
GD2 Land partitioning systems  
GD3 Coordinate systems  
GD4 Datums  
GD5 Map projections  
GD6 Data quality  
GD7 Land surveying and GPS  
GD8 Digitizing  
GD9 Field data collection  
GD10 Aerial surveys and photogrammetry  
GD11 Satellite and shipboard remote sensing  
GD12 Data standards and infrastructures

GS. GI S&T and Society  
GS1 Legal aspects of GI S&T  
GS2 Economic aspects of GI S&T  
GS3 Public use of geospatial information  
GS4 Control of geospatial information  
GS5 Dissemination of geospatial information  
GS6 Coordinating organizations  
GS7 Ethical aspects of GI S&T  
GS8 Critical GIS

OI. Organizational and Institutional Aspects  
OI1 Historical and future trends in organizational and institutional aspects  
OI2 Managing the GI system operations and infrastructure  
OI3 Organizational structures and procedures  
OI4 GI S&T workforce themes  
OI5 Institutional aspects  
OI6 Coordinating organizations

# Example Questions:

## Knowledge Area - Conceptual Foundations

Unit CF3 Domains of geographic information (Core Unit)

### Topic CF3-1 Space

Define the four basic dimensions or shapes used to describe spatial objects (i.e., points, lines, regions, volumes)

Differentiate between absolute and relative descriptions of location

Differentiate between common-sense, Cartesian/metric, relational, relativistic, phenomenological, social constructivist, and other theories of the nature of space

Discuss the contributions that different perspectives on the nature of space bring to an understanding of geographic phenomenon

Justify the discrepancies between the nature of locations in the real world and representations thereof (e.g., towns as points)

Select appropriate spatial metaphors and models of phenomena to be represented in GIS

Develop methods for representing non-Cartesian models of space in GIS

Discuss the advantages and disadvantages of the use of Cartesian/metric space as a basis for GIS and related technologies

# Key readings - Conceptual Foundations

Berry, B. J. L. (1964). Approaches to regional analysis: a synthesis. *Annals of the Association of American Geographers*, 54, 2-11. (Units CF3-CF4)

Couclelis, H. (1992). People manipulate objects (but cultivate fields): Beyond the raster-vector debate in GIS. In A. U. Frank, I. Campari, & U. Formentini, (Eds.), *Theories and methods of spatio-temporal reasoning in geographic space*. (65-77). Berlin: Springer Verlag (Unit CF4)

Egenhofer, M. J. (1991). Reasoning about binary topological relations. *Lecture Notes in Computer Science*, 525, 144-160. (Unit CF5)

Frank, A. (1998). Different types of "times" in GIS, in M. Egenhofer & R. Golledge (Eds.), *Spatial and temporal reasoning in geographic information systems* (40-62). New York: Oxford University Press. (Unit CF3)

Hägerstrand, T. (1970). What about people in regional science? *Papers, Regional Science Association*, 24, 1-21. (Units CF3, CF4)

Lakoff, G. (1987). *Women, fire, and dangerous things*. Chicago: University of Chicago Press. (Units CF1, CF2)

Egenhofer, M., & Mark, D. M. (1995). Naive geography. In A. Frank & W. Kuhn (Eds.), *Lecture*

Mark, D. M., & Freundschuh, S. M. (1995). Spatial concepts and cognitive models for geographic information use. In T. L. Nyerges, D. M. Mark, R. Laurini, & M. Egenhofer (Eds.), *Cognitive aspects of human-computer interaction for geographic information systems*. (21-28). Dordrecht: Kluwer Academic Publishers: (Unit CF2)

Mennis, J. L., Peuquet, D. J., & Qian, L. (2000). A conceptual framework for incorporating cognitive principles into geographical database representation. *International Journal of Geographical Information Science*, 14, 501-520. (Units CF2, CF4)

# Teaching Format

Question-Question

Ask it early!

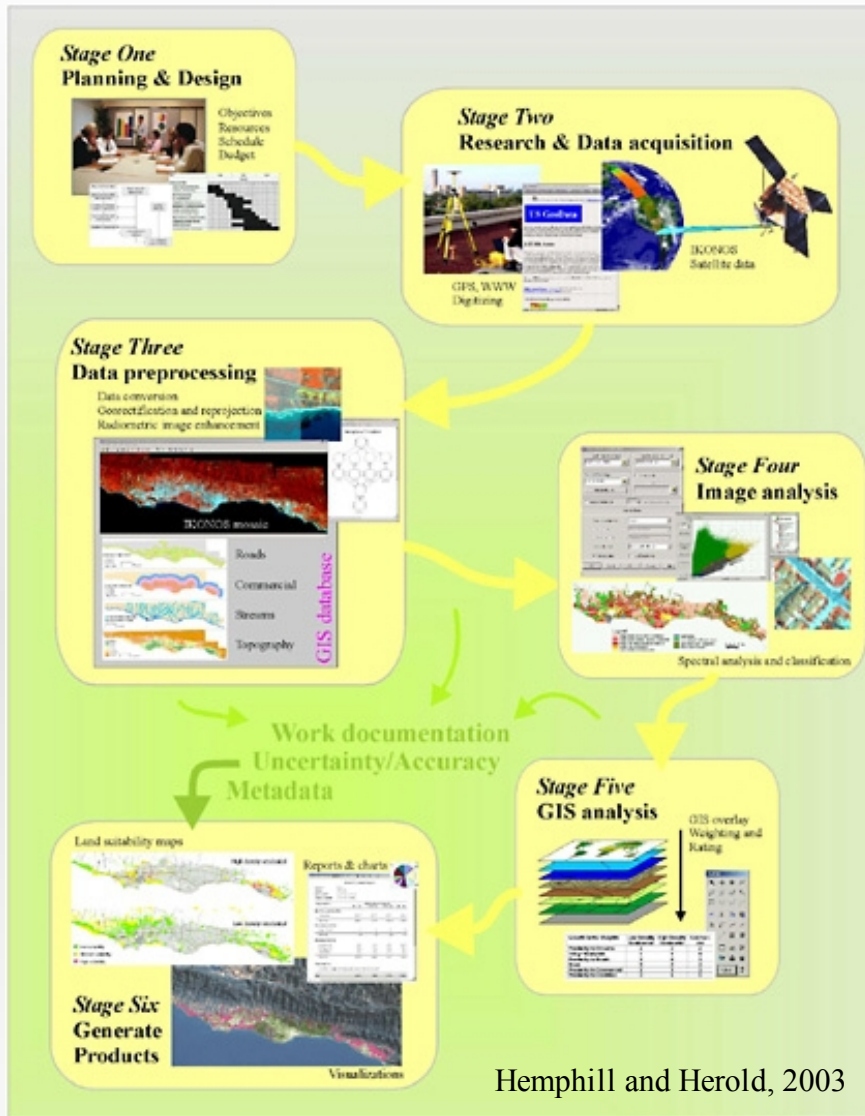
Prediction-Reflection

Self-assessment

Prediction-Revision-Decision

Policy /problem solving





GIS Research Model

Integrate stages into labs from the beginning

Emphasize the process

Multistage analysis in a pictorially based GIS

# What's Next?

Consult with GIS faculty.

Make available online.

Take cognition and learning courses.

Submit as student paper to 2008 UCGIS Summer Assembly

Publication?

Other projects:

Create GIS workshop for grad students.

Design a GIS course for pre-service social science teachers.



# Thank You

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