Start a huge, foolish, project
Like Noah.

— Rumi (13th century poet)

Challenges of Spatial Thinking Across Disciplines

Karl Grossner
Stanford University Libraries

Spatial Thinking Across the College Curriculum
Santa Barbara, CA 10-11 December 2012
We need to

• Define terms
  – spatial thinking, ability, skills, literacy, reasoning

• Enumerate overarching set of concepts to be mastered
  – an ‘integrated conception of space’

• Take lessons from
  – writing in the disciplines
  – numeracy, graphicacy, critical thinking
Spatial thinking is...

An amalgam

Concepts (knowledge)
Tools (spatial representations)
Reasoning (ways of thinking)

An attitude
- P. Bol
Benchmarks for Spatial Literacy

• What constitutes spatial literacy?
• Being conversant with core spatial concepts and principles...
• And familiar with their application in multiple scientific and humanistic fields??
• Aware of the role of spatial thinking in scientific explanation; and the “habit of mind” to use it
• Knowing that “how long is the coast of California?” is a meaningless question.
<table>
<thead>
<tr>
<th><strong>Space-time context</strong></th>
<th>space; space-time; place; landscape; setting; reference frame; object view; field view; virtual reality; the void; positive space</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primitives of identity</strong></td>
<td>identity; object; field; attribute; category; classification; hierarchy; part-whole; group</td>
</tr>
<tr>
<td>The existence, nature and naming of things in the world</td>
<td></td>
</tr>
<tr>
<td><strong>Spatial relationships</strong></td>
<td>location; distribution; orientation; gradient; proximity; adjacency; connection; containment; center-periphery; affinity; complement; symmetry; order; alignment; packing; polarity; chirality; separation; hierarchy</td>
</tr>
<tr>
<td>Relative locations of entities and their parts</td>
<td></td>
</tr>
<tr>
<td><strong>Measurement</strong></td>
<td>distance; magnitude; density; shape; connectivity; dispersion; length; size; angle; area and volume; similarity; spatial sampling; modifiable areal unit; uncertainty; comparison; duration; frequency; gradient; center; access</td>
</tr>
<tr>
<td>of objects and of relationships and related issues</td>
<td></td>
</tr>
<tr>
<td><strong>Spatial structures</strong></td>
<td>pattern; structure; boundary; network; region; neighborhood; landmark; path; surface; area; container; group; folding; route; center; branching; conduit; coil; stratum; object; part</td>
</tr>
<tr>
<td>as observed, and derived from measurement and analysis</td>
<td></td>
</tr>
<tr>
<td><strong>Dynamics</strong></td>
<td>flow diffusion; spatial interaction; motion; attraction; force; counterforce; blockage; restraint removal; balance; event and process; sequence; chaos; energetics; navigation; potential; enablement; deformation; cycle; duration; frequency; path</td>
</tr>
<tr>
<td>Distinctly spatiotemporal concepts</td>
<td></td>
</tr>
<tr>
<td><strong>Representation</strong></td>
<td>representation; map; perspective; cognitive map; route perspective; survey perspective; point; line; polygon; grid; coordinate system; units; object location recall</td>
</tr>
<tr>
<td>External tools and mental processes</td>
<td></td>
</tr>
<tr>
<td><strong>Transformations on data</strong></td>
<td>scale; spatial interpolation; spatial integration (overlay); buffer; dimensional transformation; profile; structuring; grain; time cost; space as time; map projection</td>
</tr>
<tr>
<td><strong>Spatial inference</strong></td>
<td>spatial dependence; spatial heterogeneity; distance decay; areal association; spatial model; competition for space; spatial probability; aura; congruence; similarity; access</td>
</tr>
<tr>
<td>Products of analysis and conclusions drawn</td>
<td></td>
</tr>
</tbody>
</table>
Resource Browser

We have annotated several hundred teaching resources cataloged in the National Science Digital Library with spatial concept terms listed below. We have also created a new TeachSpatial collection annotated in the same way. The concept terms were drawn from the U.S. National Science Education Standards (NSES 1996) for topic areas B - Physical Science, C - Life Science, D - Earth and Space Science, as well as from the 1994 U.S. Geography Teaching Standards for grades 5-12. These standards can be browsed here.

**spatial concept terms**

- spatial structures
- spatial properties
- space-time context
- position
- spatial dynamics
- spatial relations
- spatial interaction
- spatial transformations
- representation
- spatial principles

**NSDL teaching resources related to "surface"**

**Ocean Surface Currents Glossary**

- **resource type(s):** Text
- **Reference Material**
- **Glossary/Index**
- **cataloged by:** DLESE

This glossary provides short definitions of the oceanographic jargon used to describe ocean surface currents. It is designed to accompany the website "Ocean Surface Currents", a reference that provides information on surface currents in the world's oceans.

**Phoebe Floats!**

- **resource type(s):** Award/Recognition
- **Scholarship**
- **Event**
- **cataloged by:** MathDL

This paper uses Archimedes' Law of Floating Bodies to determine how far a ball sinks below the surface, and also examines an interesting wrinkle involving the chaotic behavior of Newton's method applied to a cubic polynomial.

**Collaborative Surface Migration Behavior of Proteus mirabilis**

- **resource type(s):** Movie/Animation
- **Audio/Visual**
- **cataloged by:** ben

Collaborative migration behavior exerted by Proteus mirabilis cells on the surface of a low-agar medium. The organisms were differentiating into elongated hyperflagellates and gathering for migration.
Discipline-diving

• Geography
  – Many studies, e.g. Golledge, Goodchild, Janelle, Bednarz(s), Unwin, Kuhn, ...

• Geosciences
  – Liben and Titus, Kastens, Manduca,

• Chemistry, Meteorology, Physics, Surgery
  – Hegarty

• Computation across E-Science
  – Gahegan
For historical scholarship...

- spatial infrastructure pivotal to demonstrating the value
  - gazetteers
  - data repositories

- core spatial concepts
  - space v. place
  - location
  - distance
Measuring Hellenization

http://www.stanford.edu/dept/classics/cgi-bin/web/projects

"Measuring Hellenization"
ORBIT The Stanford Geospatial Network Model of the Roman World

Mapping ORBIT Interactive distance cartogram Map gallery

Query and Results

- Start: Ephesus
- Destination: Naissus
- Month of travel: June
- Priority: fastest, cheapest, shortest
- Network mode: Road, Coastal sea
- River: Military, Civilian
- Sea: Faster, Slower
- Road options: Speed options
- Price options: Donkey/camel, Wagon, Passenger carriage

Spatial Thinking Across Disciplines

Santa Barbara, CA 10-11 December 2012
Spatial Thinking Across Disciplines

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GEOGRAHPHERS @ UCSB

- geography
- geomorphology
- ecology
- hydrology
- geology
- biogeography
- oceanography
- geographic information science
- environmental psychology
- analytical cartography
- urban and regional planning
- geophysical fluid dynamics
- environmental systems engineering
- civil engineering
- meteorology
• Individual and household level
• Neighborhood level
• Region level
• Multi-scale

“...a desire to blur the boundaries of the disciplines”
Social sciences

- Sociology
- Political Science
- Economics
- Anthropology
- History
- Geography
- ...

Spatially Integrated Social Science
Spatially Integrated {everything}?
Socrates
...in these chance utterances were involved two principles, the essence of which it would be gratifying to learn, if art could teach it.

Phaedrus
What principles?

Socrates
That of **perceiving and bringing together in one idea the scattered particulars**, that one may make clear by definition the particular thing which he wishes to explain...Certainly by this means the discourse acquired clearness and consistency.

Phaedrus
And what is the other principle, Socrates?

Socrates
That of **dividing things again by classes, where the natural joints are**, and not trying to break any part, after the manner of a bad carver.
you might be a...

- chemist or materials scientist
- archaeologist
- astronomer, astrophysicist
- political scientist
- artist, critic or theorist
- environmental historian
- historian

- geographer

- literary historian

- economist
- neurobiologist
- meteorologist

who wants to explain

- molecular bonds
- 7,000 BCE house plan
- galaxy formation
- voting behavior
- a painting, a dance piece
- urban greenness
- administrative control structures in China over millennia
- the effective shrinking/shrivel ing/ flattening of geographic space
- WRT time, expense and evolving technology
- diffusion of a genre during the Enlightenment
- globalization
- the structure of the retina
- Hurricane Sandy
who wants to explain

- molecular bonds
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in terms of...

- connection, orientation, attraction
- adjacency
- diffusion, expansion, condensation
- pattern, cluster
- symmetry, balance, flow, motion
- density, cluster, proximity, access
- network, spatial interaction, hierarchy
- distance, cost distance
- flow, spatial interaction
- dispersion, flow
- pattern, spatial autocorrelation
- trajectory, convection
who wants to design

- molecular bonds
- 7,000 BCE house plan
- galaxy formation
- voting behavior
- a painting, a dance piece
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Differentiate to Integrate?

• Cognitive psychologists asking what spatial thinking means to
  – Social sciences, incl. human geography
  – Physical sciences at various scales
    • nano, molecular, geographic, cosmic
  – Engineering (design) at various scales
    • tools, bodies → buildings → cities
  – Historians
  – Arts and Letters