Making Sense Of Spatial Thinking Frameworks For Broad Geoscience Education Research

Peggy McNeal
Towson University

Heather Petcovic
Western Michigan University
How inappropriate to call this planet Earth when it is quite clearly Ocean.

-Arthur C. Clark
Geoscience Education Research (GER) Grand Challenges Research Themes

Solid Earth

Cognitive – Spatial and Temporal Reasoning

Fluid Earth

Conceptual Understanding – Environment, Ocean, Atmosphere, Climate

Conceptual Understanding – Solid Earth

• What skills and tasks are essential to the different specialties within the geosciences?

• Do current measures of spatial and temporal reasoning accurately assess the skills required in the various geoscience specialties?

Case in point

Atit, K., Shipley, T. F., & Tikoff, B. (2013). Twisting space: are rigid and non-rigid mental transformations separate spatial skills?. *Cognitive processing, 14*(2), 163-173
1. Internal and External Spatial Frameworks

2. Spatial versus Object Visualizers

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3. Cattell-Horn-Carroll (CHC) Theory

G: Overall human intelligence

Gv = visual processing

11 narrow factors are components of visual processing

4. Geography: Spatial Thinking Ability Test (STAT)

1. Comprehending orientation and direction
2. Comparing map information to graphic information
3. Choosing the best location based on several spatial factors
4. Imagining a slope profile based on a topographic map
5. Correlating spatially distributed phenomena
6. Mentally visualizing 3-D images based on 2-D information
7. Overlaying and dissolving maps
8. Comprehending geographic features represented as point, line, or polygon

5. Spatial Thinking in the Geosciences

5. Spatial Thinking in the Geosciences

Spatial skills that meteorologists report using:
- Disembedding
- Mental Animation
- Perspective taking


6. Top-Down Typology for the Structure of Spatial Intellect

<table>
<thead>
<tr>
<th>Perspective taking</th>
<th>Locating self and other objects</th>
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<tbody>
<tr>
<td>Relations among objects, including self, in space</td>
<td>Alignment</td>
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<tr>
<td>Updating movement through space</td>
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<table>
<thead>
<tr>
<th>Visualizing 3D from 2D</th>
<th>Disembedding</th>
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<tr>
<td>Penetrative thinking</td>
<td>Categorization</td>
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<td>Mental transformations</td>
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<td>Sequential thinking</td>
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7. A Heuristic Framework of Spatial Ability

What’s missing?

Comprehending both inertial and rotational frames of references, i.e., the Coriolis force, is important to understanding the fluid Earth.
<table>
<thead>
<tr>
<th>Approach</th>
<th>Authors, Date</th>
<th>Main take-away</th>
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<tbody>
<tr>
<td>Internal and External Frameworks</td>
<td>Bryant, Tversky &amp; Franklin, 1992</td>
<td>Describes how using different perspectives while forming mental models influences task processing</td>
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<tr>
<td>Spatial versus Object Visualizers</td>
<td>Kozhevnikov, Kosslyn &amp; Shephard, 2005</td>
<td>Illustrates different cognitive styles for encoding and processing images</td>
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<td>Spatial Ability Thinking Test</td>
<td>Lee &amp; Bednarz, 2012</td>
<td>Integrates geography content knowledge and spatial skills</td>
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<tr>
<td>Spatial Thinking in the Geosciences</td>
<td>Manduca and Kastens, 2012</td>
<td>Maps the domain of spatial thinking in the geosciences</td>
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<tr>
<td>CHC Theory (bottom-up factor analysis)</td>
<td>McGrew, 2009</td>
<td>Identifies 11 narrow abilities that are components of visual processing</td>
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<tr>
<td>A Heuristic Framework of Spatial Ability</td>
<td>Buckley, Seery, &amp; Canty, 2018</td>
<td>Extends 11 narrow abilities and introduces a static-dynamic distinction</td>
</tr>
<tr>
<td>Typology for the structure of spatial intellect</td>
<td>Newcombe &amp; Shipley, 2015</td>
<td>Organizing schema based on intrinsic-extrinsic and static-dynamic</td>
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Questions to ponder going forward...

• What can fluid Earth education researchers learn from prior spatial thinking research in geology, geography, and other STEM subjects?
• Which spatial thinking frameworks (if any) align best with skills necessary for understanding and learning about the fluid Earth?
• Should mapping the domain of spatial thinking for fluid Earth sciences be a priority for continued research in atmospheric, oceanic and climate science?
• Are existing tests sufficient for research in fluid Earth sciences? i.e., Spatial Scaling Test, Perspective Taking/Spatial Orientation Test, Hidden Figures Test, Paper Folding, and Form Boards