Making Sense Of Spatial Thinking Frameworks For Broad Geoscience Education Research

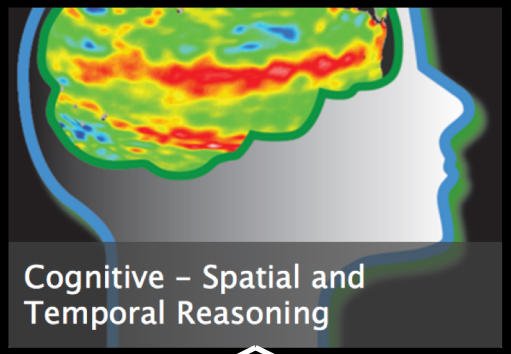
Peggy McNeal
Towson University

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

Fluid Earth

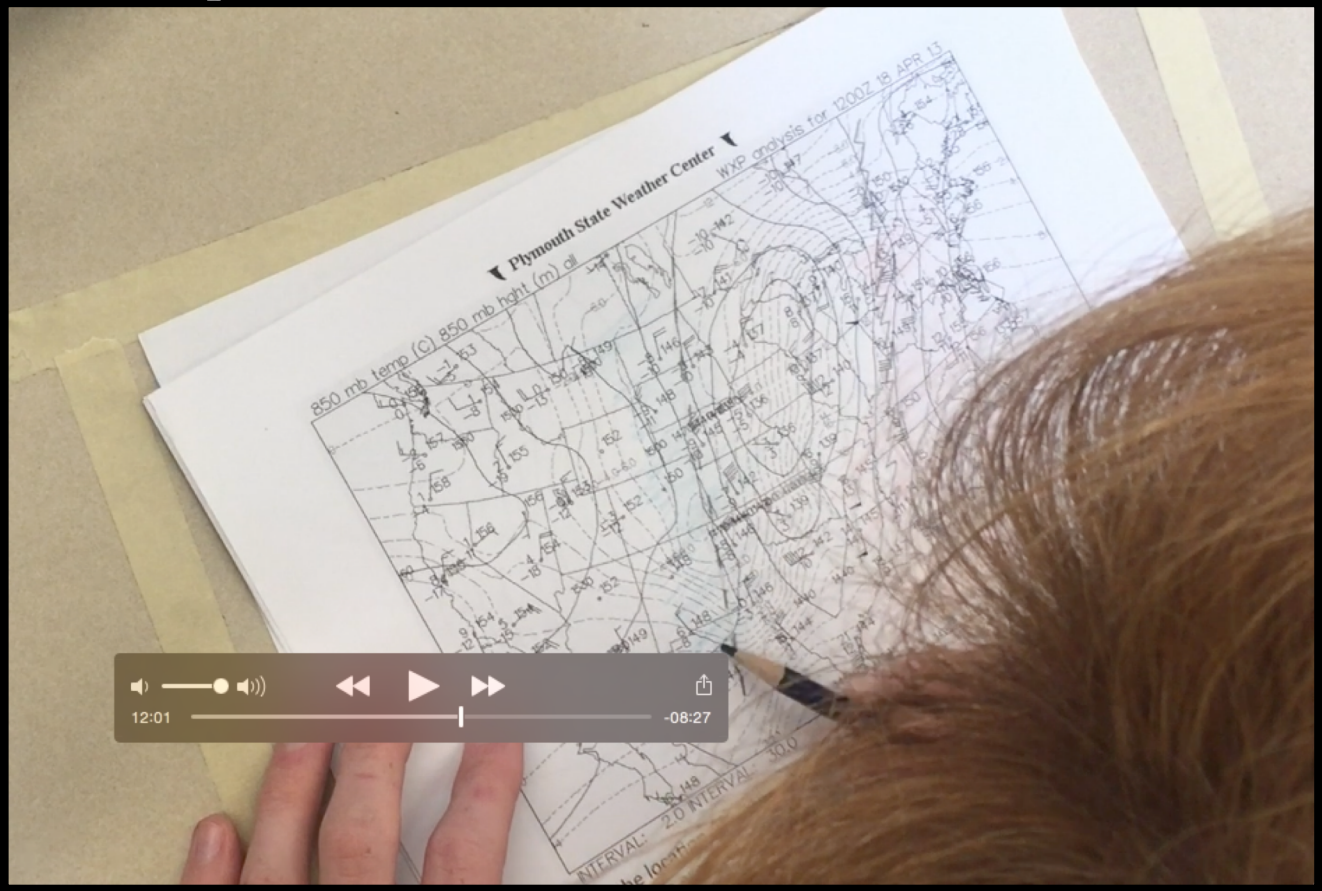
St. John, K. (Ed.) (2018). *A Community Framework for Geoscience Education Research*. National Association of Geoscience Teachers. Retrieved from https://doi.org/10.25885/ger_framework/15

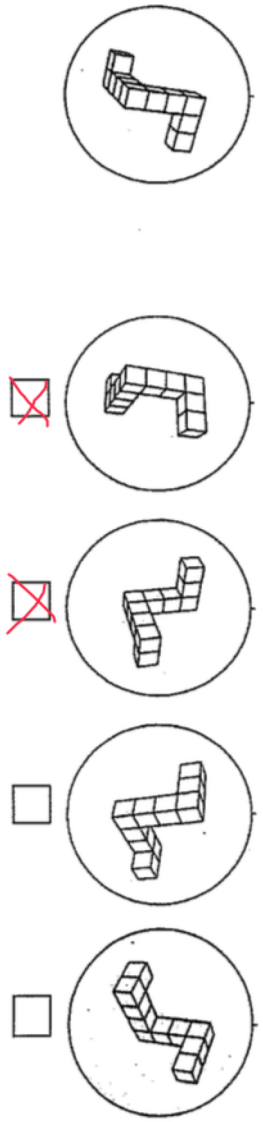
GER Grand Challenges Research Themes

- 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?

St. John, K. (Ed.) (2018). *A Community Framework for Geoscience Education Research*. National Association of Geoscience Teachers. Retrieved from https://doi.org/10.25885/ger_framework/15

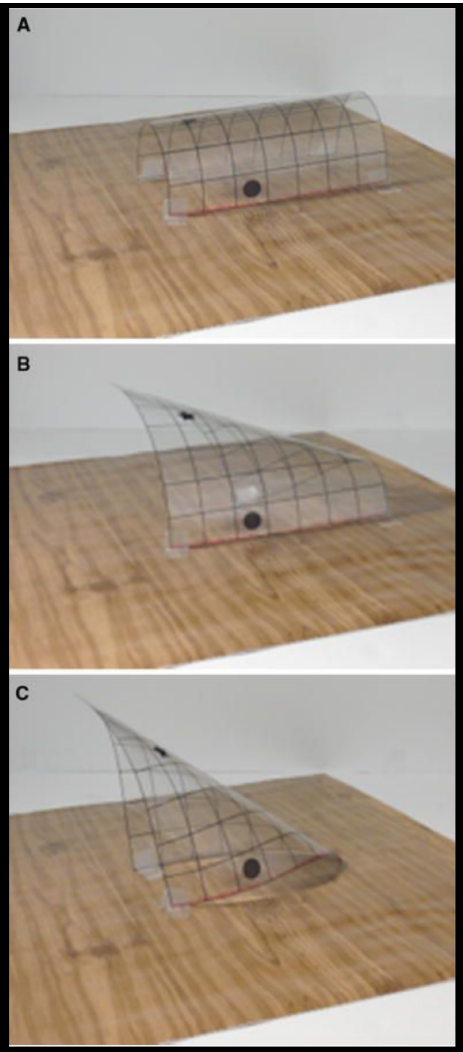
Case in point





McNeal, P., Petcovic, H., LaDue, N., & Ellis, T. (In review). Identifying Significant Cognitive Factors for Practicing and Learning Meteorology. *Journal of Operational Meteorology*,

Case in point

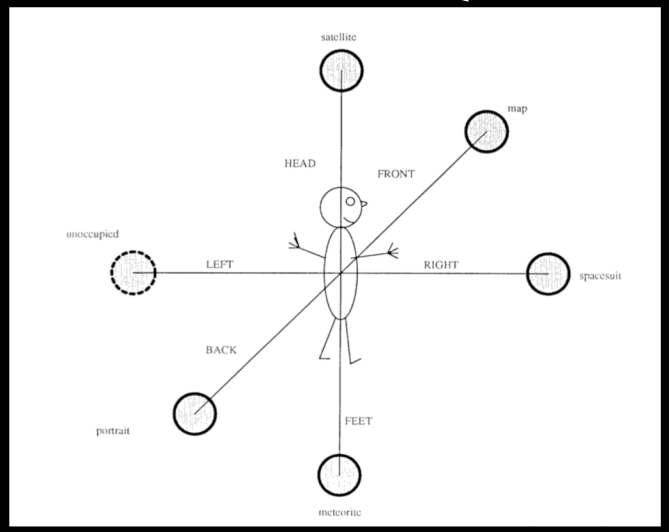


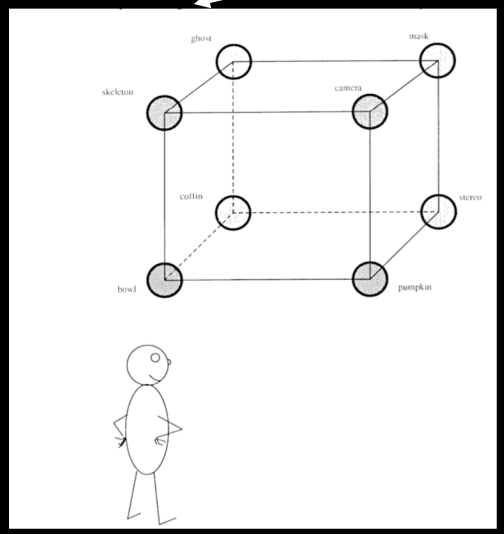
Atit, K., Shipley, T. F., & Tikoff, B. (2013). Twisting space: are rigid and non-rigid mental transformations separate spatial skills?. *Cognitive processing*, *14*(2), 163-173

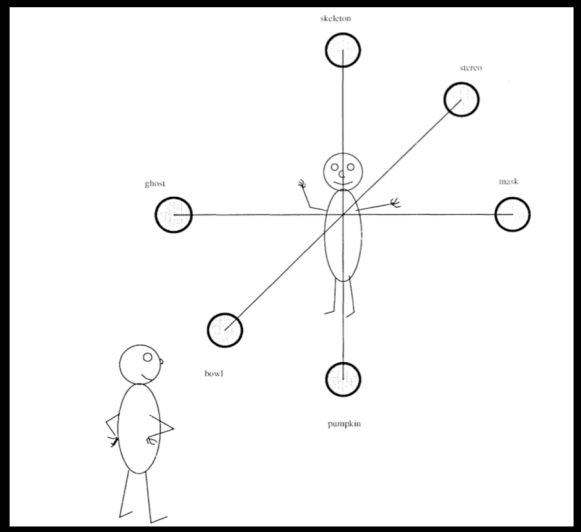
1. Internal and External Spatial Frameworks

geologist immersed in the field

meteorologist viewing atmosphere remotely

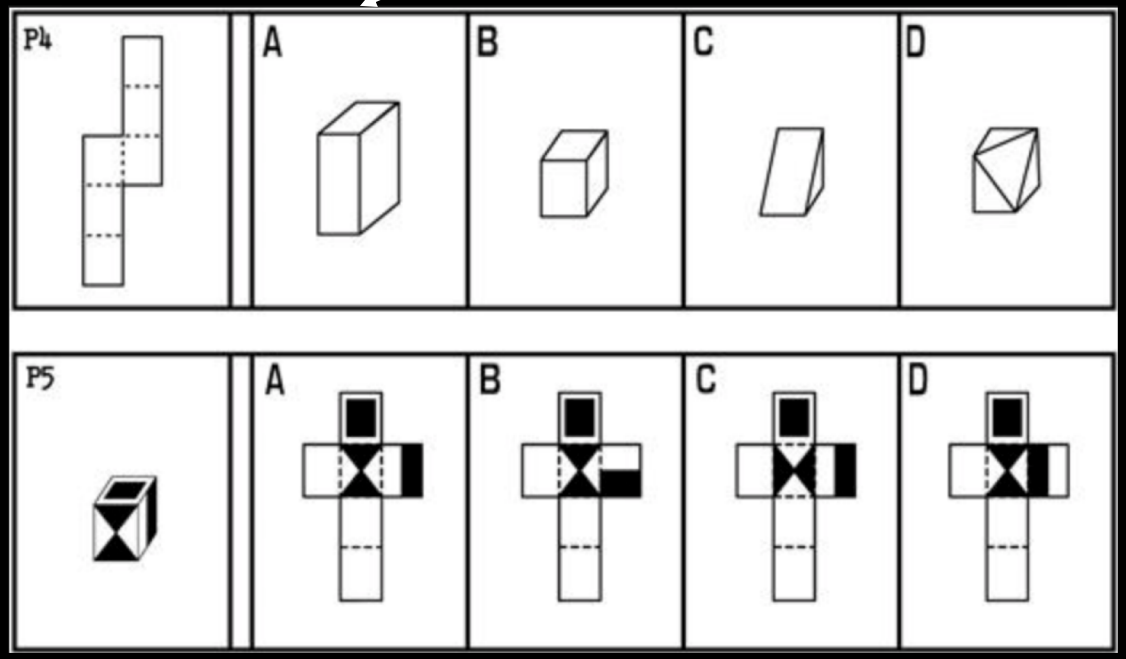


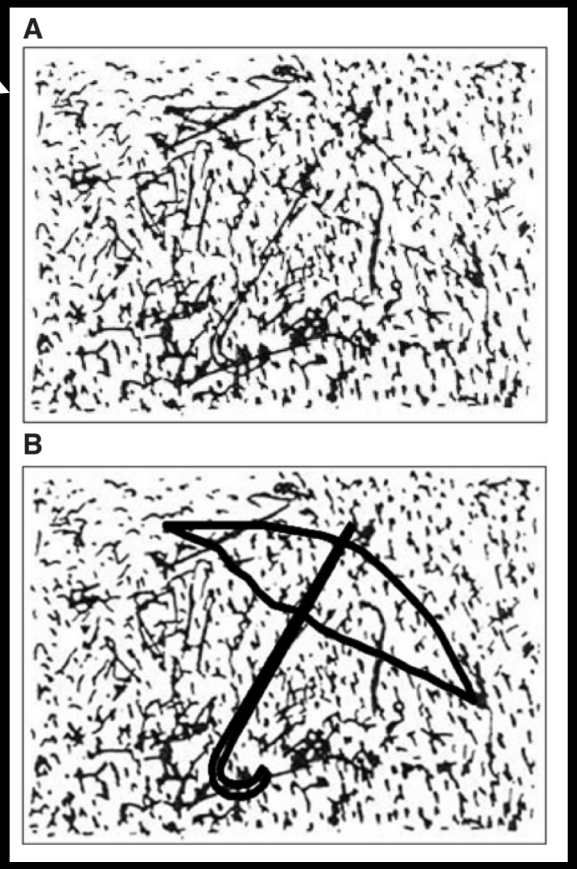




Bryant, D. J., Tversky, B., & Franklin, N. (1992). Internal and external spatial frameworks for representing described scenes. *Journal of Memory and Language, 31*(1), 74.

2. Spatial versus Object Visualizers





Kozhevnikov, M., Kosslyn, S., & Shephard, J. (2005). Spatial versus object visualizers: A new characterization of visual cognitive style. *Memory & cognition*, 33(4), 710-726.

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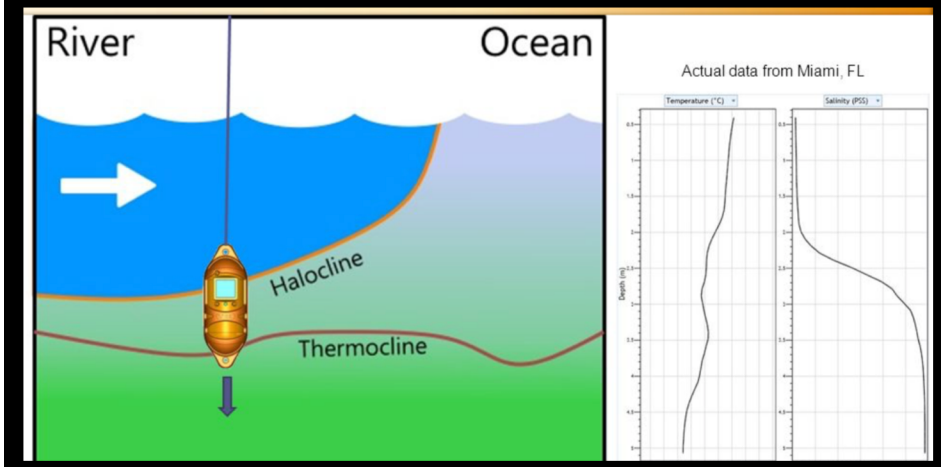

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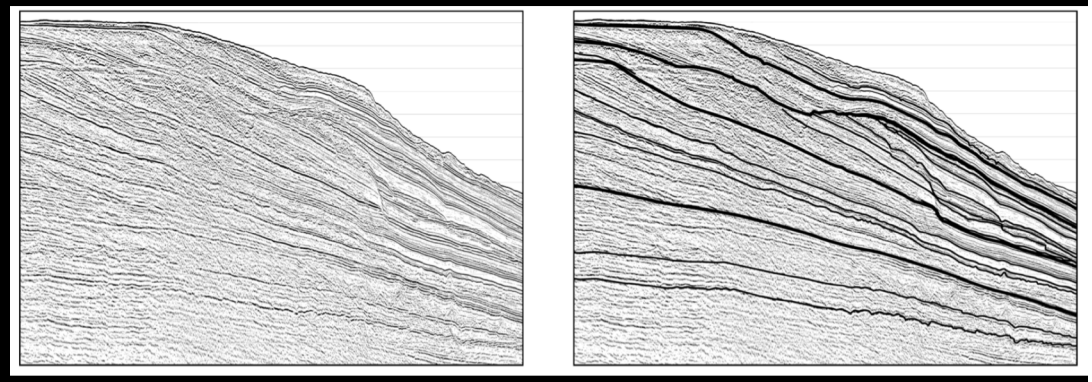
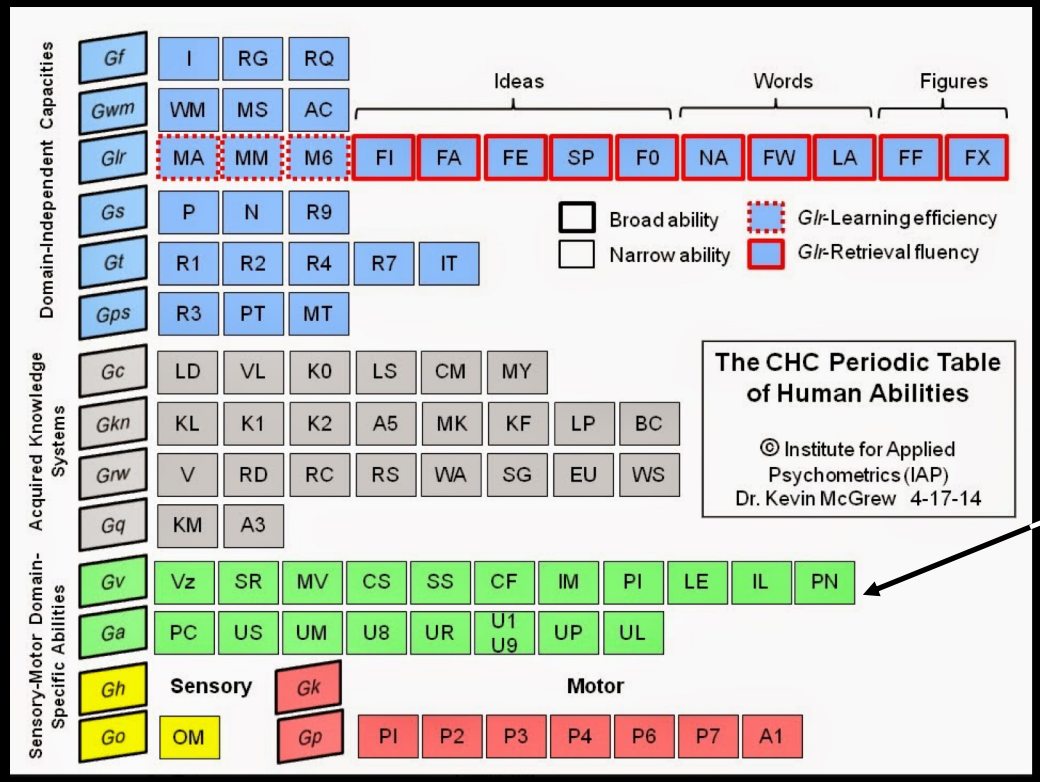


Kastens, K. (2010). Commentary: Object and spatial visualization in geosciences. *Journal of Geoscience Education*, 58(2), 52-57.

3. Cattell-Horn-Carroll (CHC) Theory

G: Overall human intelligence



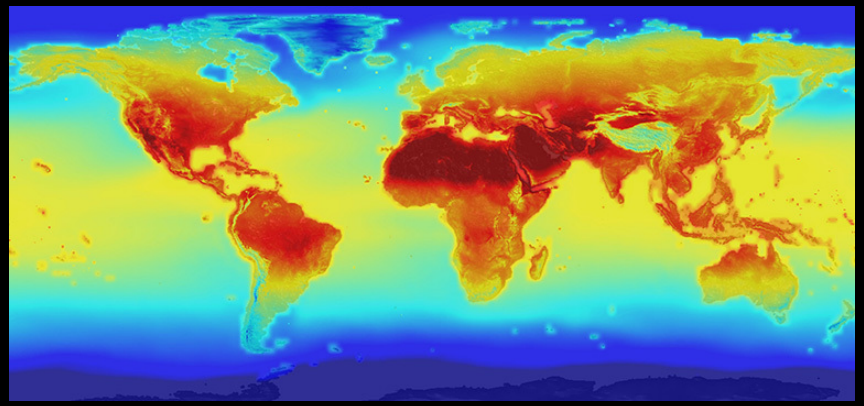
G_v=visual processing

11 narrow factors are components of visual processing

McGrew, K. S. (2009). CHC theory and the human cognitive abilities project: Standing on the shoulders of the giants of psychometric intelligence research. *Intelligence* (37) 1–10 .

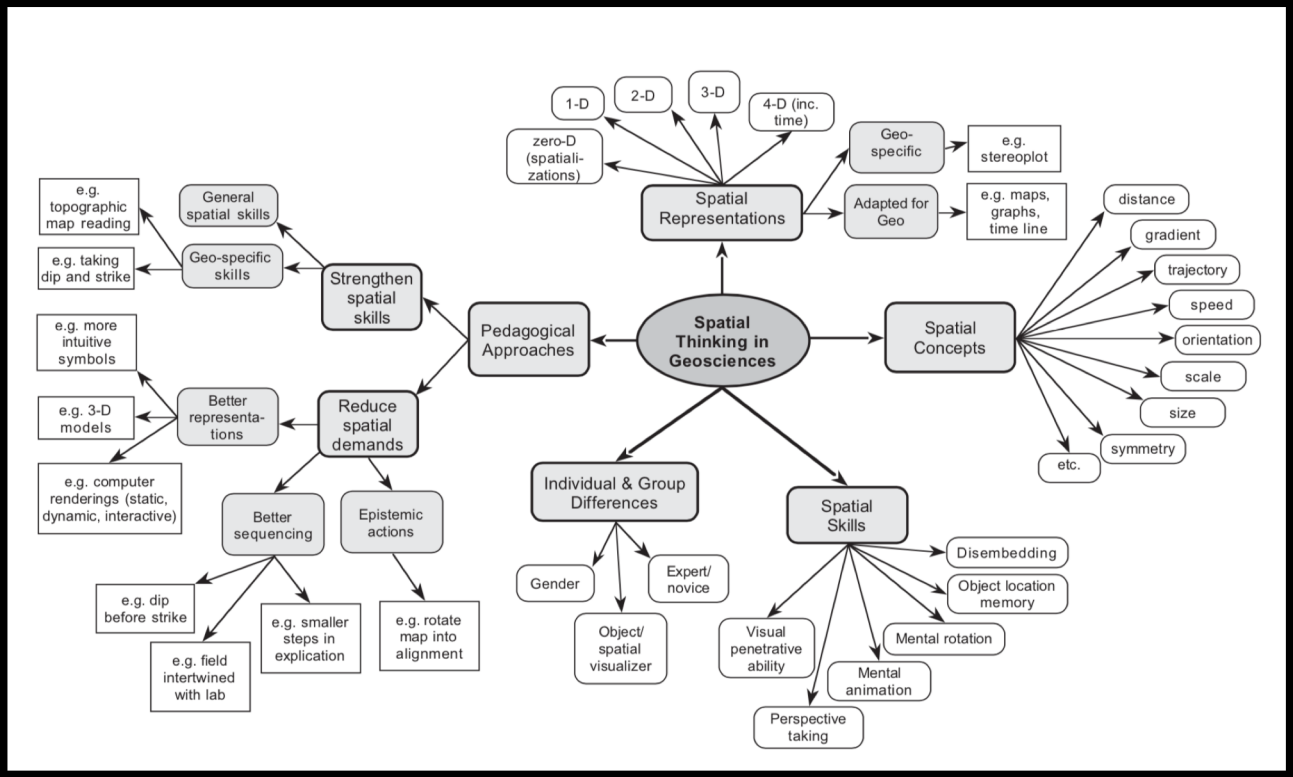
4. Geography: Spatial Thinking Ability Test (STAT)

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



Lee, J., & Bednarz, R. (2012). Components of spatial thinking: Evidence from a spatial thinking ability test. *Journal of Geography*, 111(1), 15-26.

5. Spatial Thinking in the Geosciences



Manduca, C. A., & Kastens, K. A. (2012). Mapping the domain of spatial thinking in the geosciences. Earth and mind II: A synthesis of research on thinking and learning in the geosciences. Geological Society of America Special Paper, 486, 45-49.

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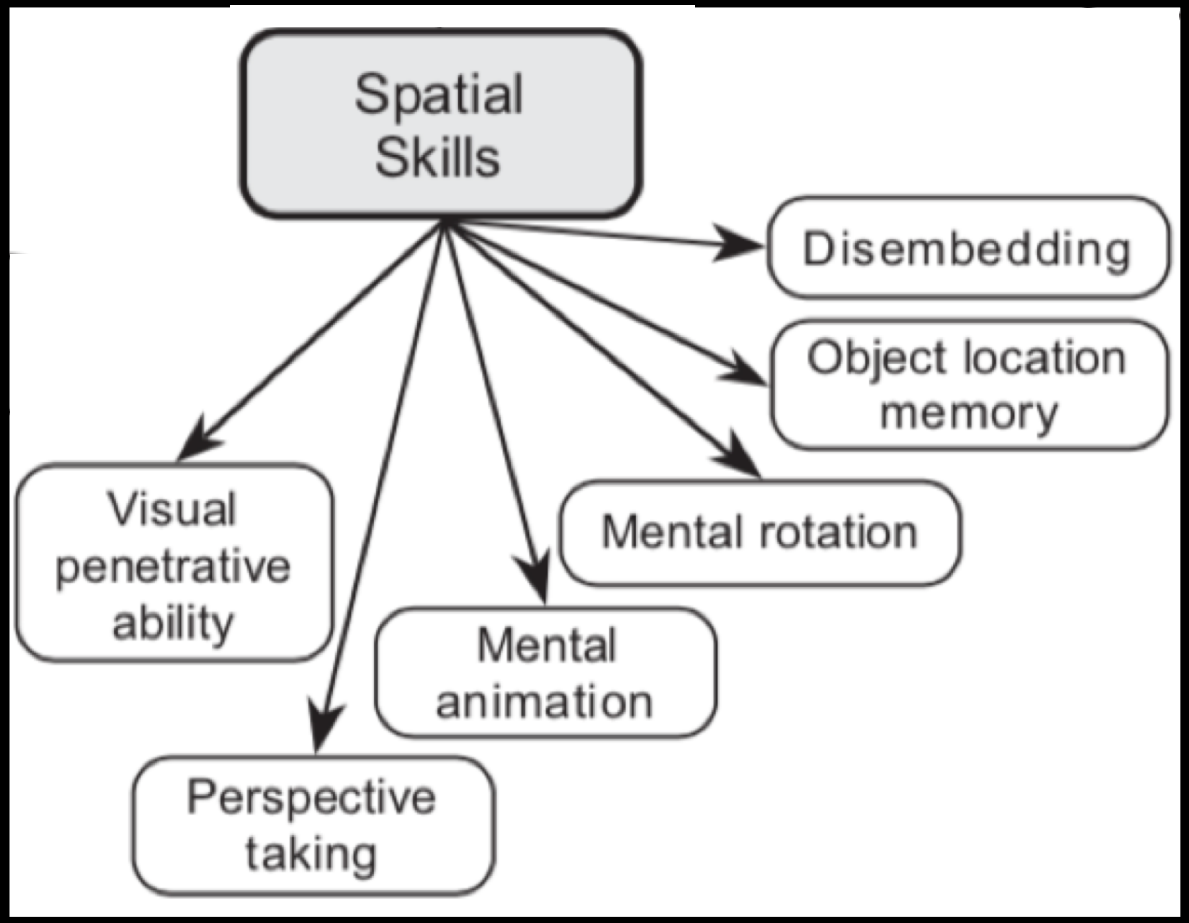


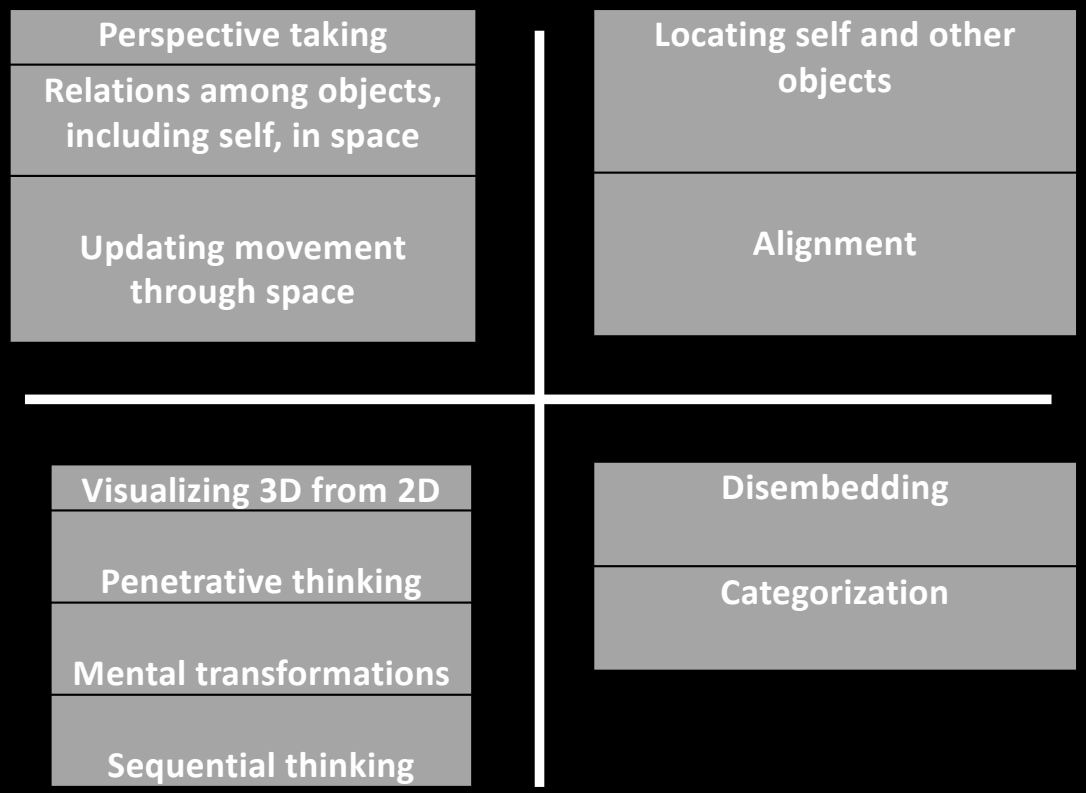
Spatial skills that meteorologists report using:

- **Disembedding**
- **Mental Animation**
- **Perspective taking**

McNeal, P., Ellis, T., & Petcovic, H. (2018). Investigating the foundations of spatial thinking in meteorology. *Journal of Geoscience Education*, *66*(3), 246-257.

Manduca, C. A., & Kastens, K. A. (2012). Mapping the domain of spatial thinking in the geosciences. Earth and mind II: A synthesis of research on thinking and learning in the geosciences. Geological Society of America Special Paper, 486, 45-49.

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



Newcombe, N. S., & Shipley, T. F. (2015). *Thinking about spatial thinking: New typology, new assessments*. In Studying visual and spatial reasoning for design creativity (pp. 179-192). Springer, Dordrecht.

7. A Heuristic Framework of Spatial Ability

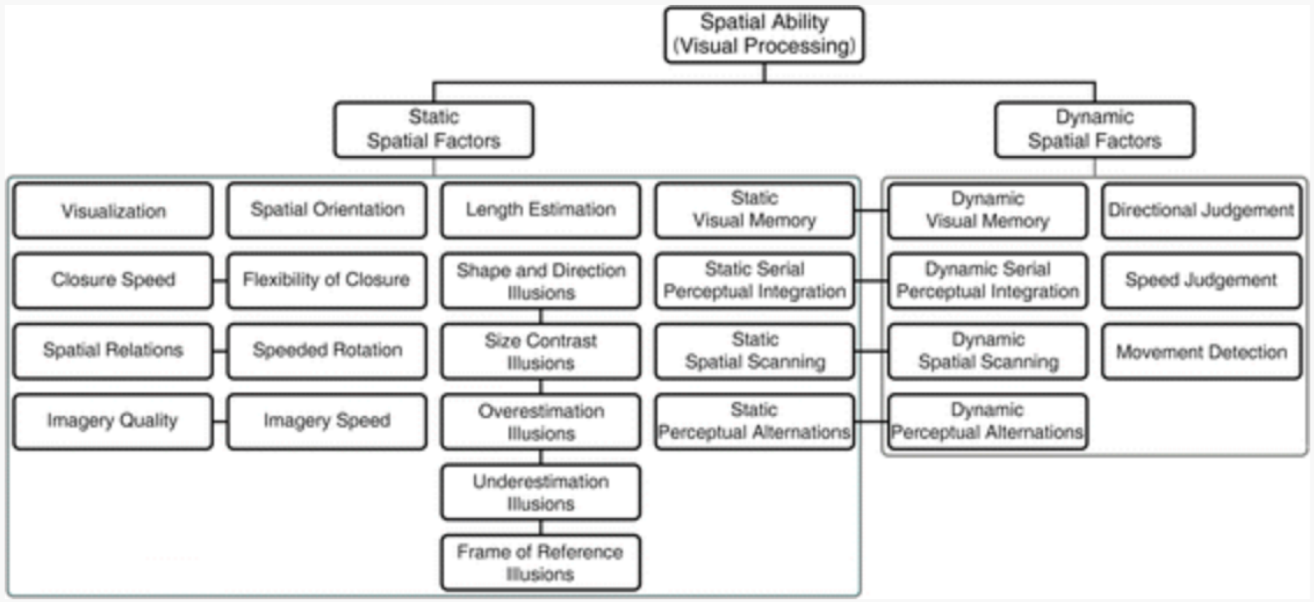
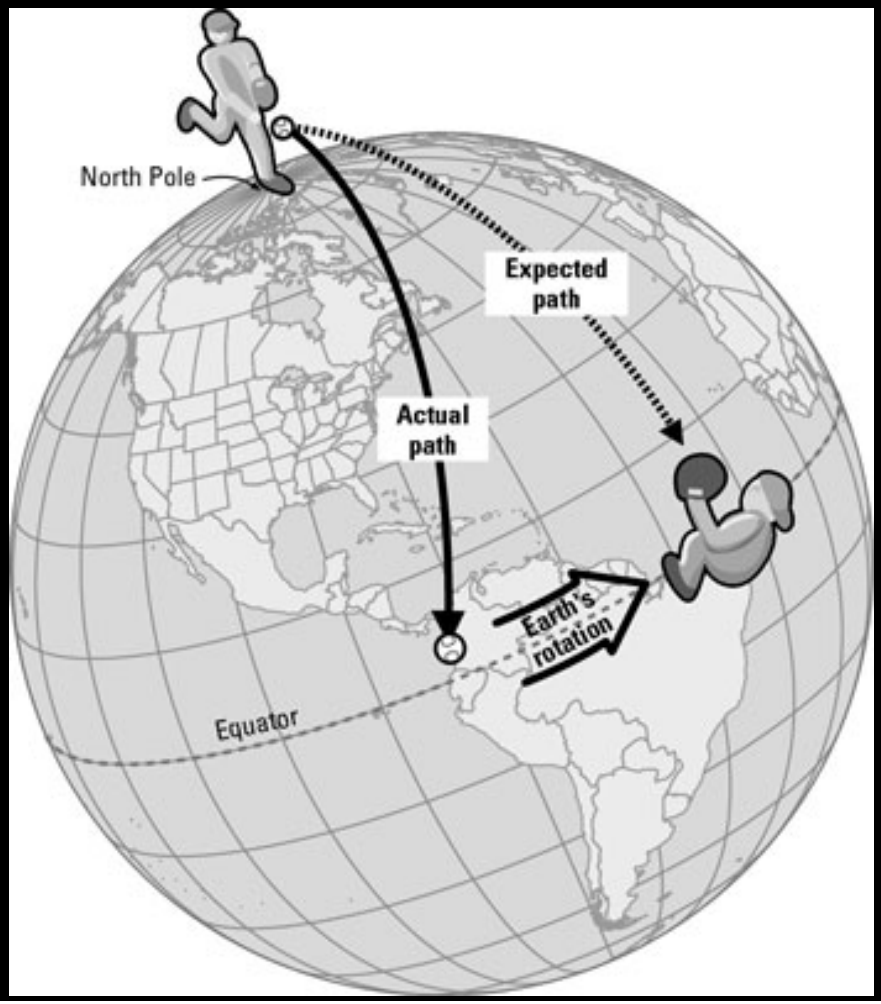


Fig. 2

Theoretical extended framework of spatial ability

Buckley, J., Seery, N., & Canty, D. (2018). A heuristic framework of spatial ability: A review and synthesis of spatial factor literature to support its translation into STEM education. *Educational Psychology Review,* 1-26.

What's missing?



Comprehending both inertial and rotational frames of references, i.e., the Coriolis force, is important to understanding the fluid Earth.

	Approach	Authors, Date	Main take-away
Describes how one views spatial information	Internal and External Frameworks	Bryant, Tversky & Franklin, 1992	Describes how using different perspectives while forming mental models influences task processing
	Spatial versus Object Visualizers	Kozhevnikov, Kosslyn & Shephard, 2005	Illustrates different cognitive styles for encoding and processing images
Describes skills necessary for a discipline	Spatial Ability Thinking Test	Lee & Bednarz, 2012	Integrates geography content knowledge and spatial skills
	Spatial Thinking in the Geosciences	Manduca and Kastens, 2012	Maps the domain of spatial thinking in the geosciences
Describes intelligence factors contributing to visual processing	CHC Theory (bottom-up factor analysis)	McGrew, 2009	Identifies 11 narrow abilities that are components of visual processing
	A Heuristic Framework of Spatial Ability	Buckley, Seery, & Canty, 2018	Extends 11 narrow abilities and introduces a static-dynamic distinction
A top-down analysis of the nature of spatial thinking	Typology for the structure of spatial intellect	Newcombe & Shipley, 2015	Organizing schema based on intrinsic-extrinsic and static-dynamic

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