Geoscience Students' Spatial Thinking Skills: Results From Multi-Institutional Classroom Studies

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http://www.spatialintelligence.org

SILC: Spatial Intelligence and Learning Center

- NSF Science of Learning Center
- SILC brings together researchers from cognitive science, psychology, computer science, education and neuroscience with K12 teachers and college/university educators in geoscience and engineering to
  - Understand spatial learning
  - Use this understanding to develop programs that will transform educational practice
- Our focus within SILC: the relationship between spatial thinking skills and the ability to perform geoscience tasks

Research Questions & Goal

- What spatial skills do students bring to undergraduate geoscience classes?
- How do geoscience courses affect students' spatial skills?
- What are the components of spatial thinking, and to what extent do they correlate? (If a student excels at mental rotation, will she excel at all spatial tasks?)

- Baseline for understanding spatial thinking skill development in the geoscience classroom

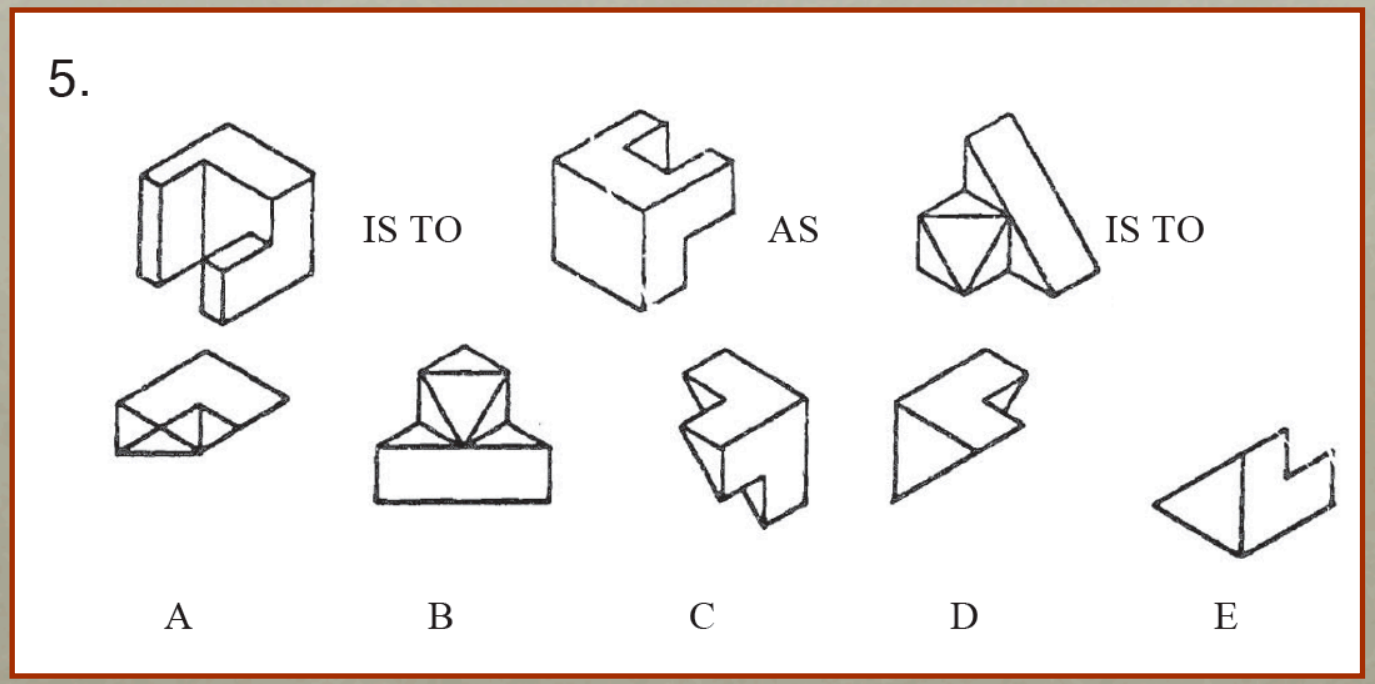
Spatial Thinking Skills Studied

Spatial Skill	Examples of geoscience applications
Mental rotation	Crystal symmetry Retrodeforming structures to infer pre-tectonic geometries
Disembedding (finding the signal in noisy data)	Interpreting seismic reflection profiles
Penetrative thinking	Visualizing a slice through any object at any scale… Visualizing subsurface geology of any kind
Sequential reasoning based on spatial relationships	Inferring a sequence of events from an outcrop, a cross-section, a geologic map, a block diagram….

(These are not the only relevant spatial skills; they are the ones I'm going to focus on today, in part because they are pervasive and important in our curricula.)

Classroom Study Design

- Pre- and post-tests of students' spatial thinking skills
  - Mental rotation test in every classroom
  - One or two additional tests in most courses
  - Standard psychometric tests and geoscience versions thereof



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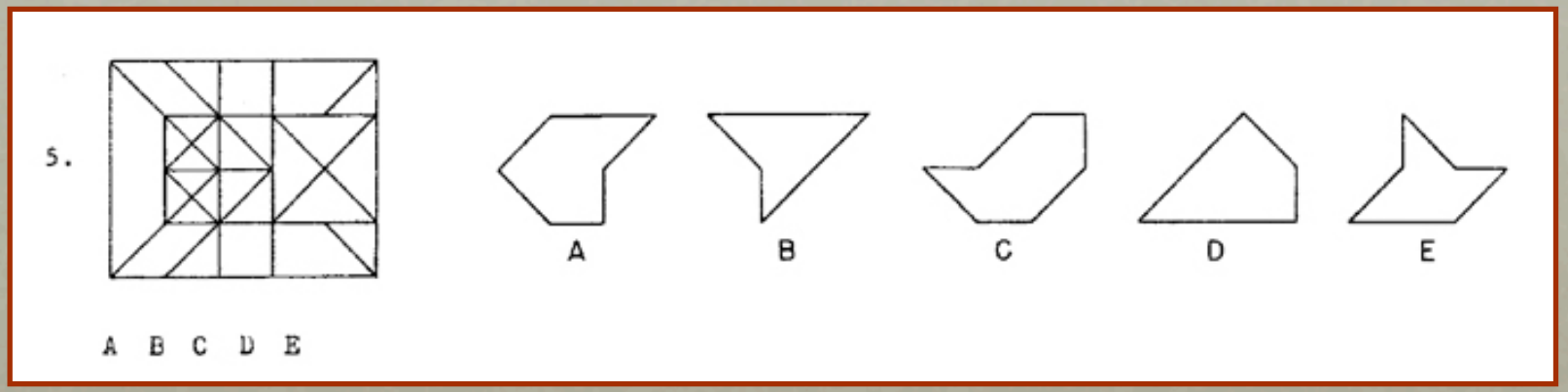

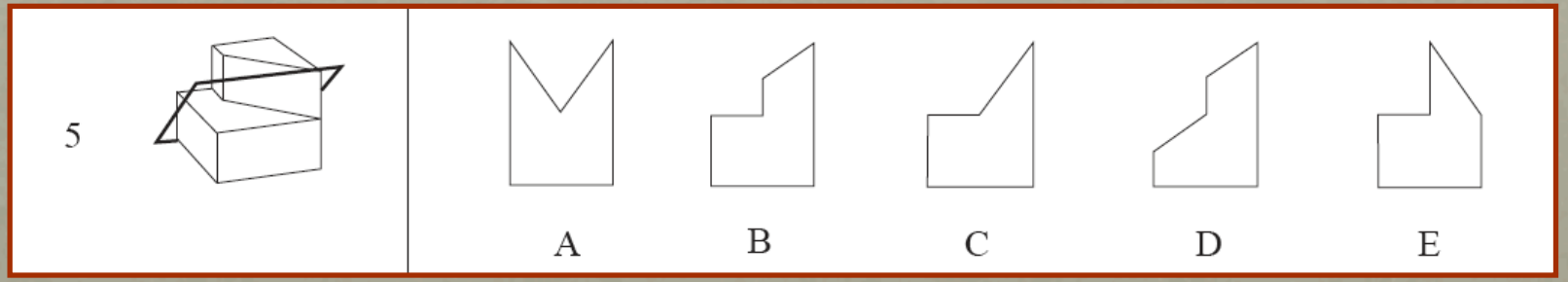

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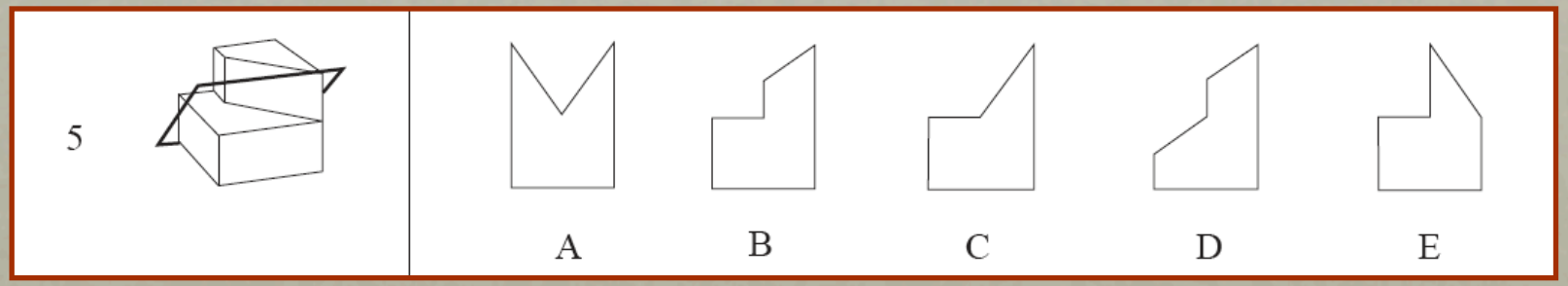
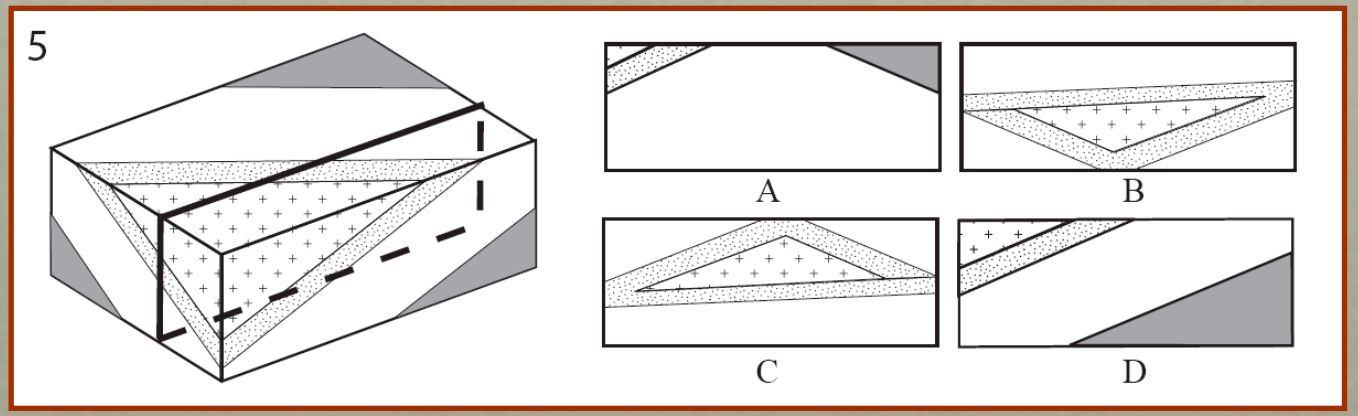




Classroom Study Design

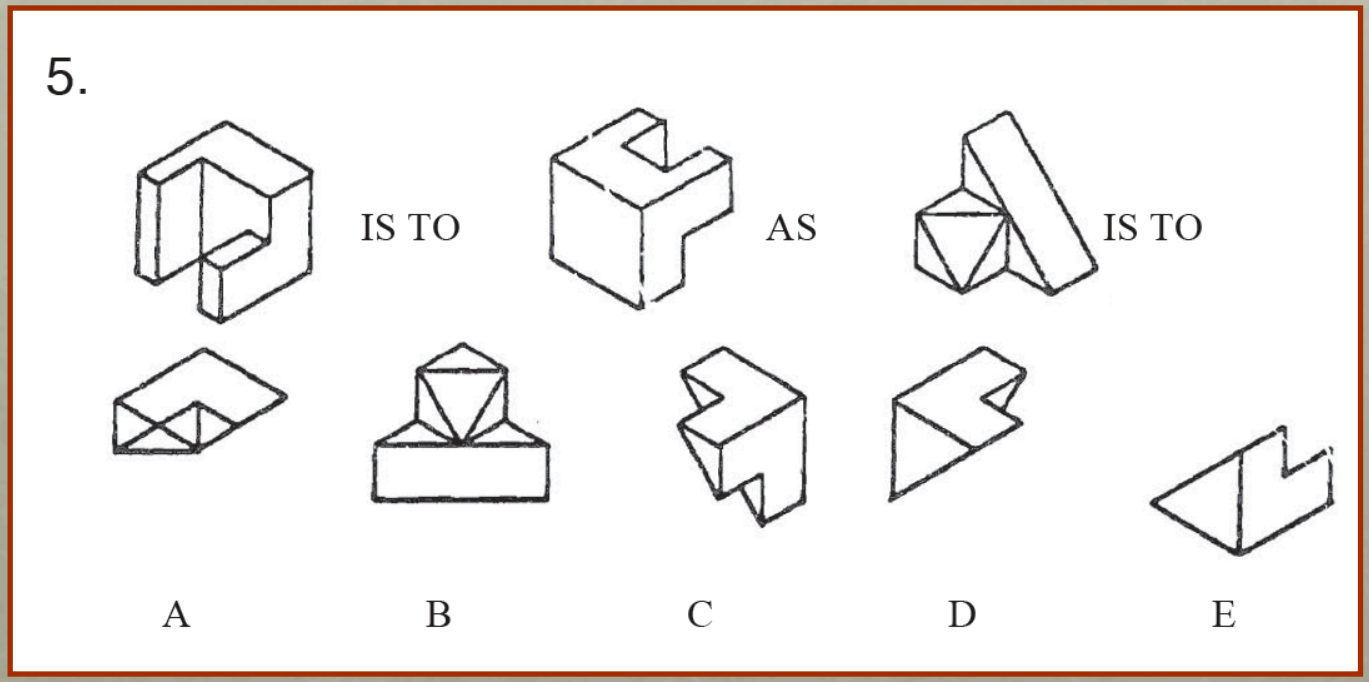
- Multiple geoscience courses at three institutions, over the course of two academic years (2008-2010)

	Intro	Min'logy	Sed/Strat	Structure	Hydro	Tectonics
UW-Madison	N=130			N=17		
Carleton College	N=41	N=19		N=21	N=8*	N=15
University of St. Thomas			N=12			

* Many of the Hydrogeology students were also enrolled in Mineralogy or Structure and took the tests in those courses. In most of the analyses that follow, the students in upper-level Carleton courses are considered as a single population.

Results: Mental Rotation

- What spatial skills do students bring to undergraduate geoscience classes?
- How do geoscience courses affect students' spatial skills?



Results: Mental Rotation, Introductory Geology courses

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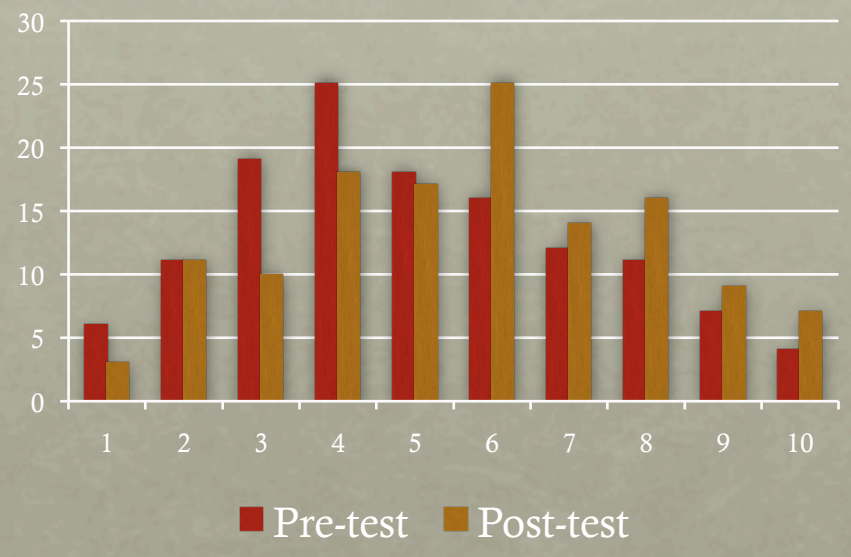
UW-Madison, Intro Geology, Spring 2010



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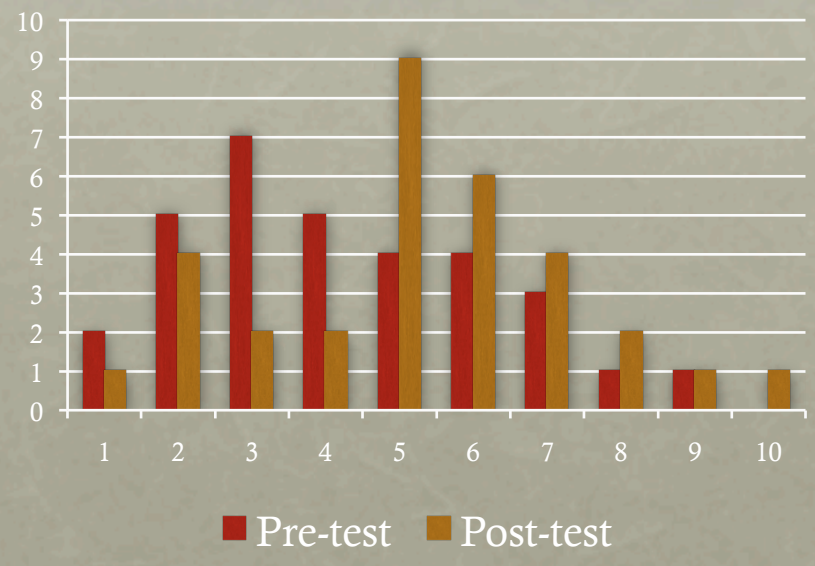
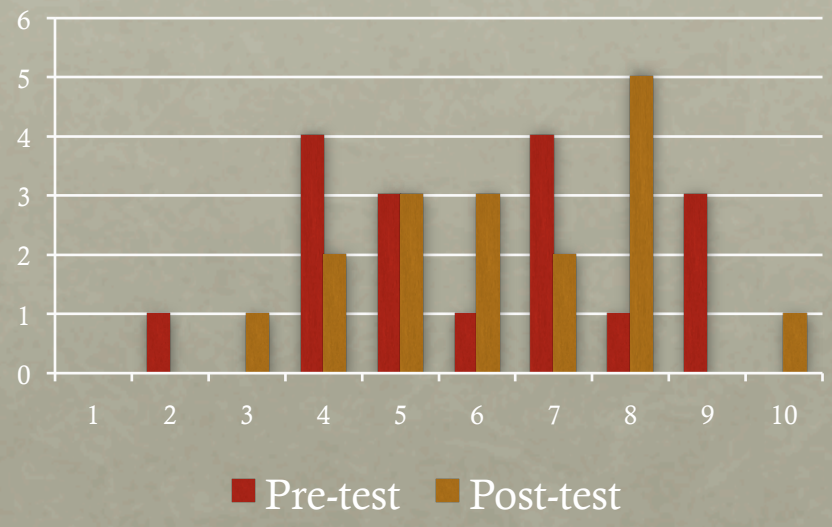


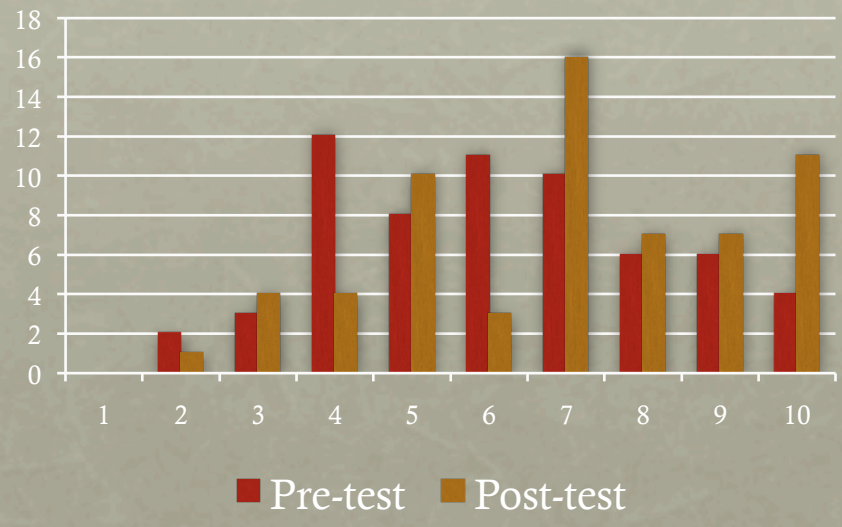
Results: Mental Rotation, Upper-level Geology courses

- What spatial skills do students bring to undergraduate geoscience classes?
- How do geoscience courses affect students' spatial skills?

UW-Madison, Structural Geol., Spring 2010



Carleton, upper level geology courses



Results: Disembedding*

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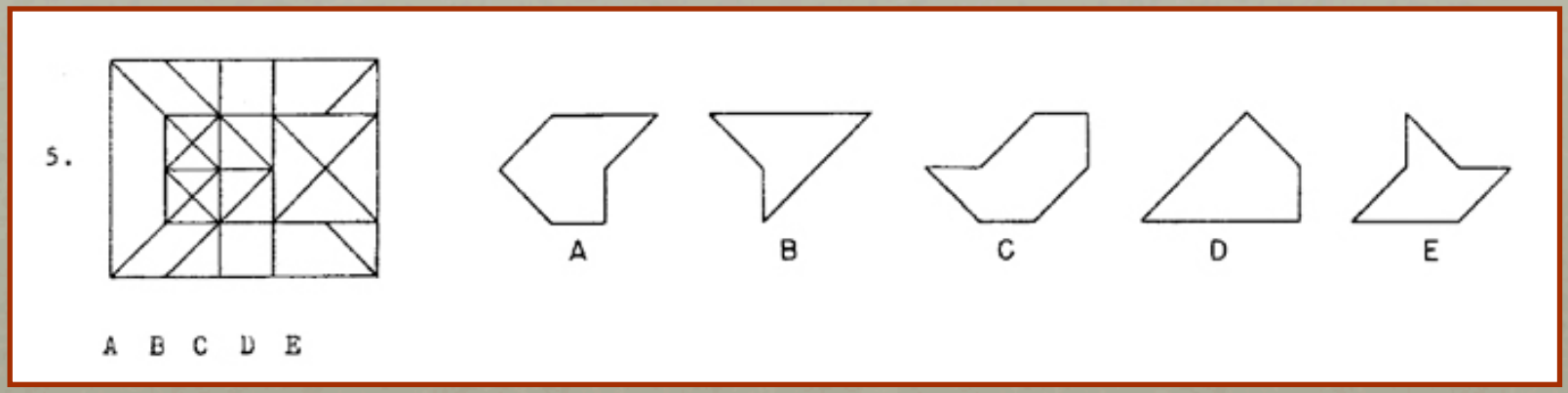

* Disembedding: isolating and attending to one aspect of a complex display or scene

Results: Disembedding, Introductory Geology courses

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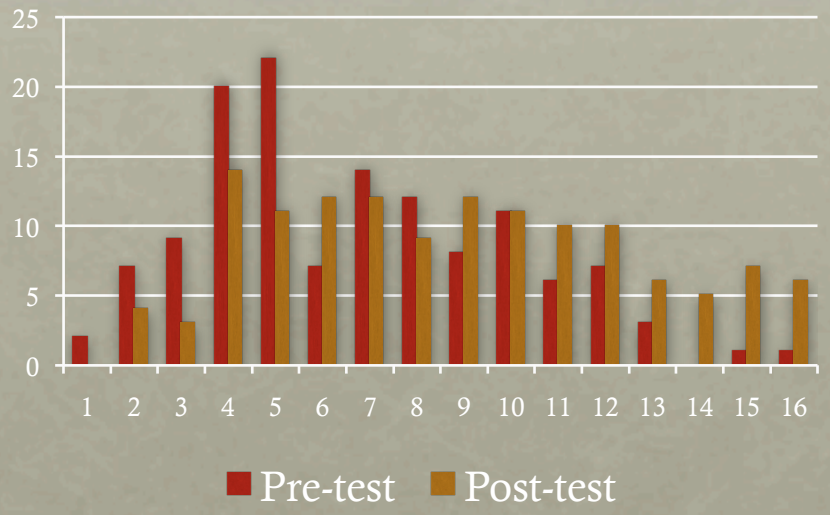
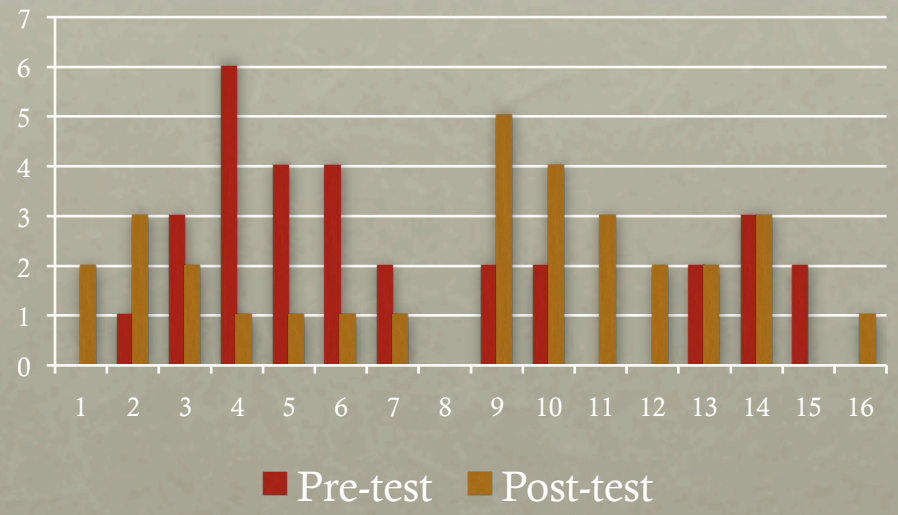
UW-Madison, Geology 100, Spr 2010



Carleton, Intro Geology, Spring 2010



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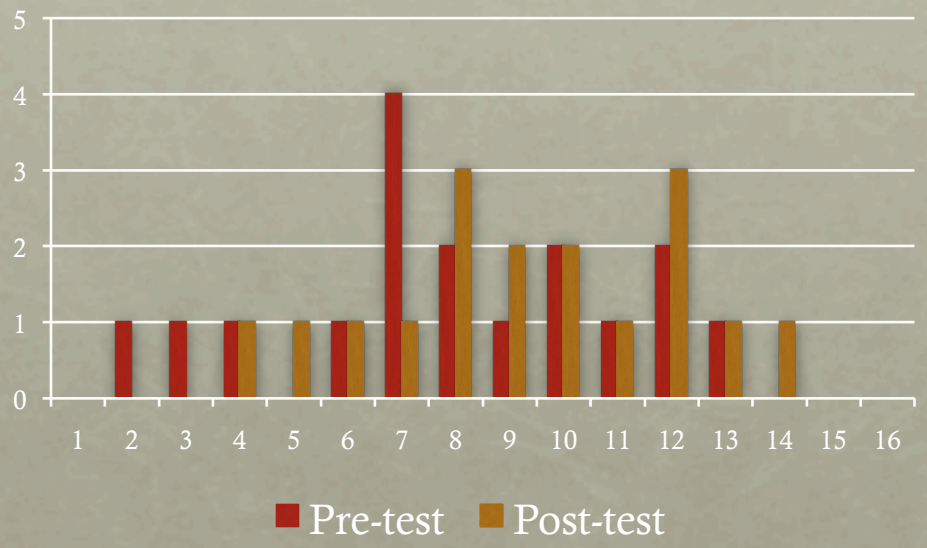
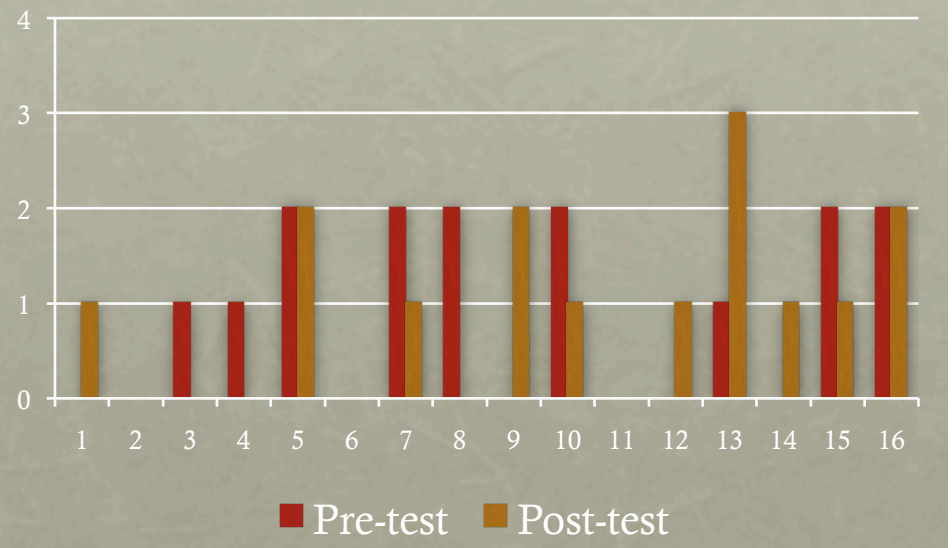


Carleton, Tectonics, Winter 2010



Results: Penetrative Thinking*

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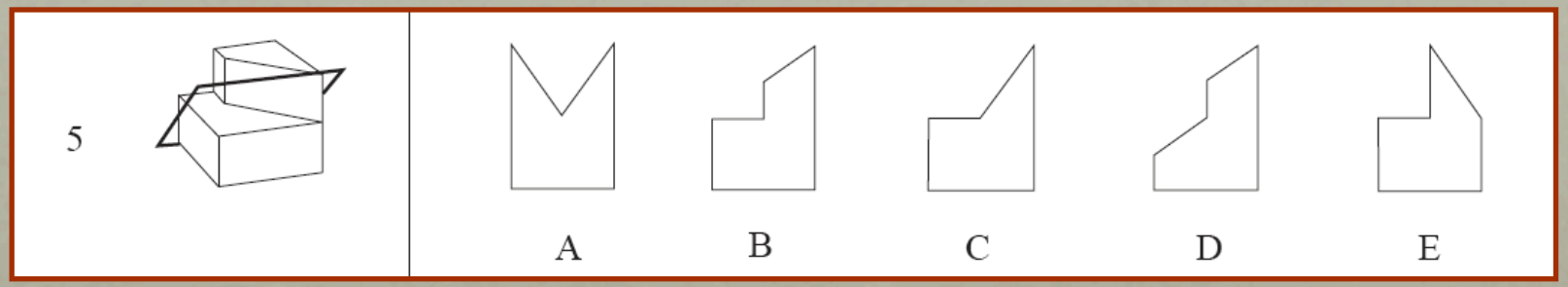

* Penetrative thinking: visualizing spatial relations inside an object

Results: Penetrative Thinking, Upper level Geology courses

- What spatial skills do students bring to undergraduate geoscience classes?
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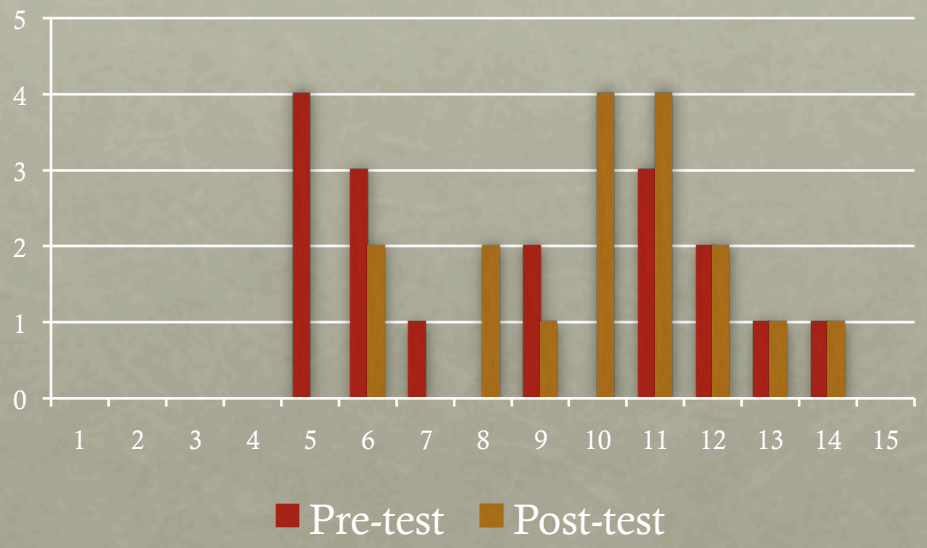
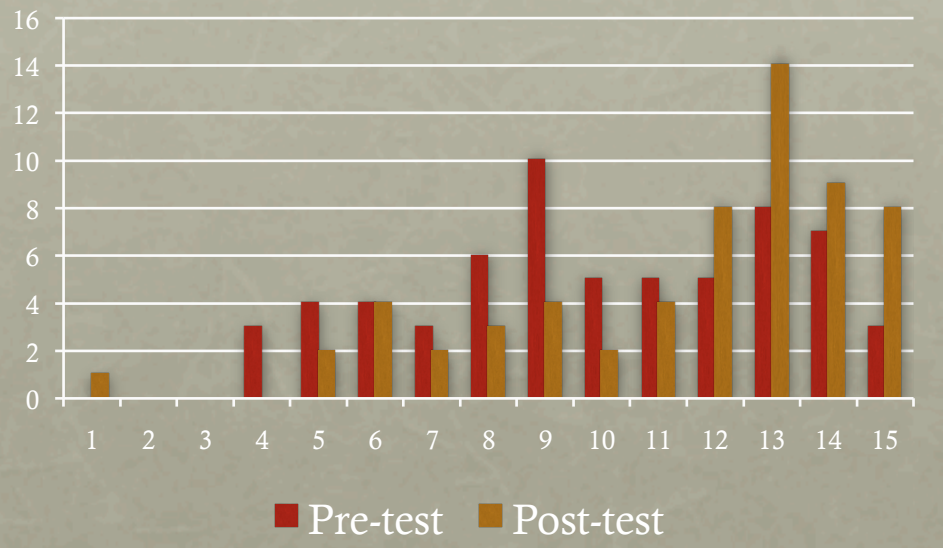
UW-Madison, Structural Geol., Spring 2010



Carleton, upper level geology courses



Results: Sequential Reasoning based on Spatial Relationships

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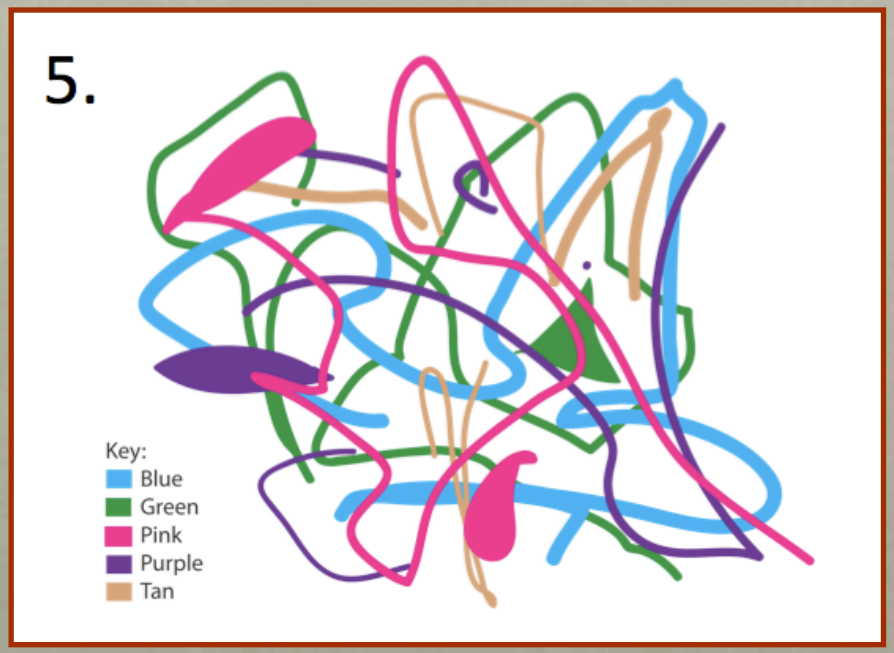

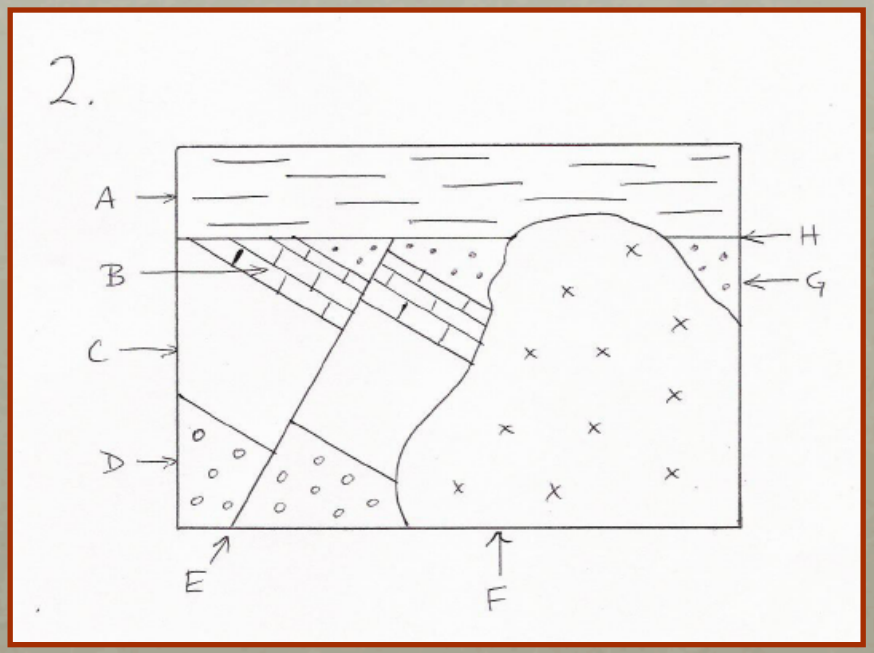

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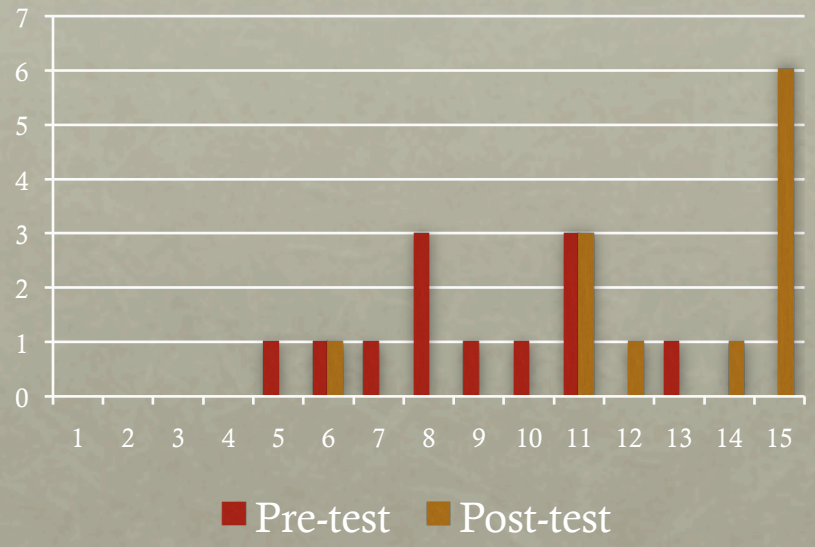
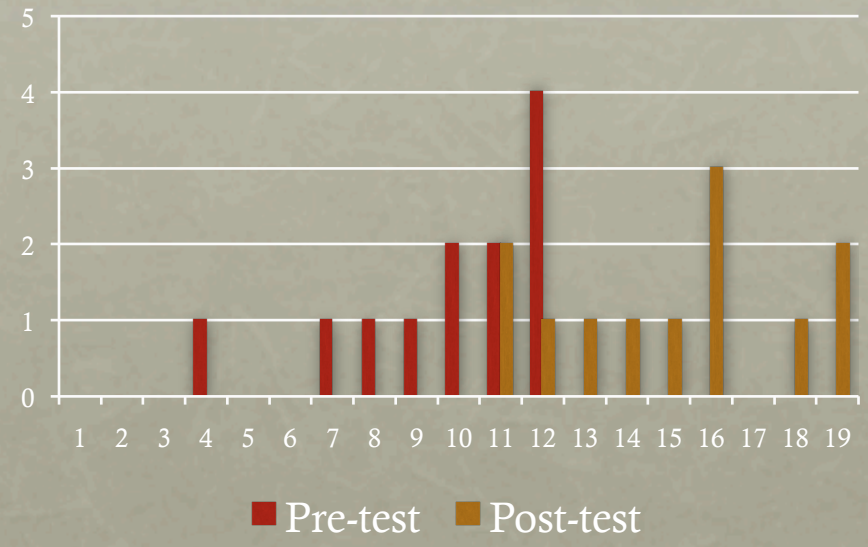
St. Thomas University, Sedimentology and Stratigraphy, Spring 2010

Color sequences ("Pollock" test)



Geological sequences



Results: Spatial Skills Correlations

- What are the components of spatial thinking, and to what extent do they correlate? (If a student excels at mental rotation, will she excel at all spatial tasks?)

Correlations	MRT/PT (N = 80)	MRT/disembed (N = 194)	PT/disembed (N = 33)
R (pre-tests)	0.46	0.28	0.51
R^2 (pre-tests)	0.21	0.08	0.26
R (post-tests)	0.52	0.33	0.16
R^2 (post-tests)	0.27	0.11	0.03

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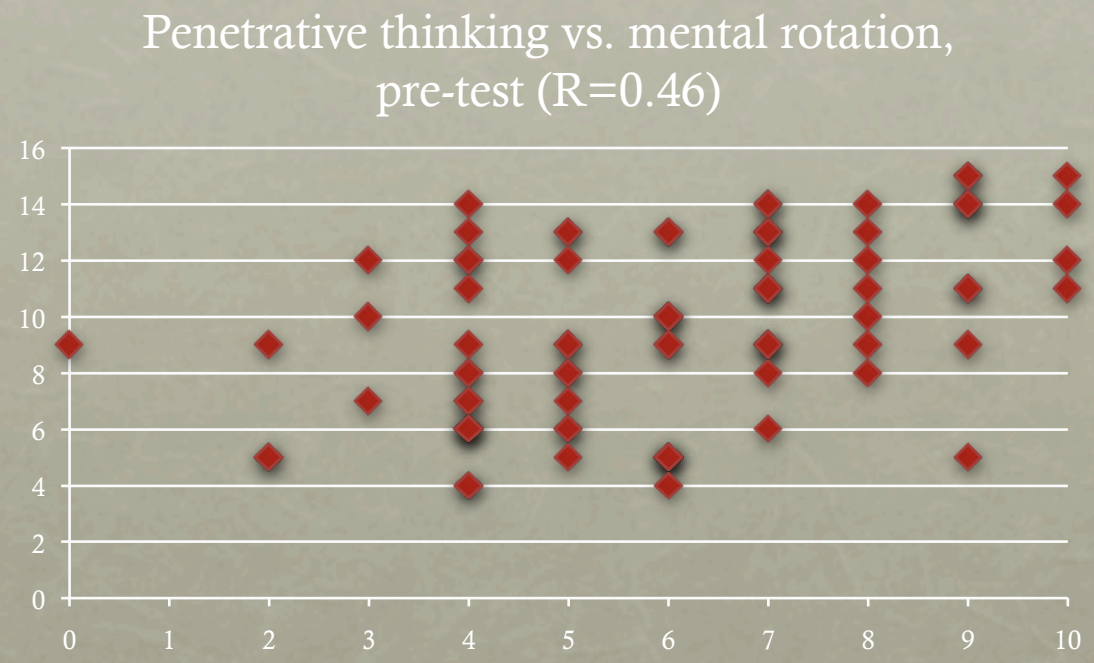
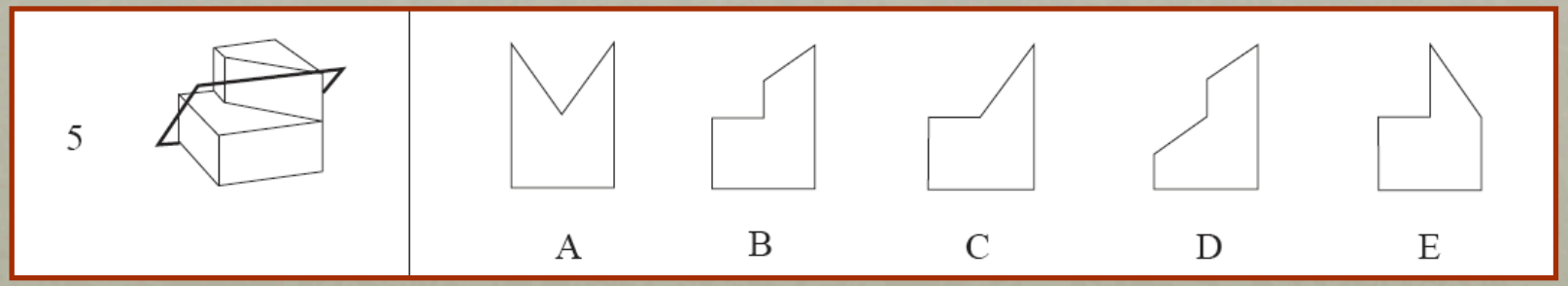
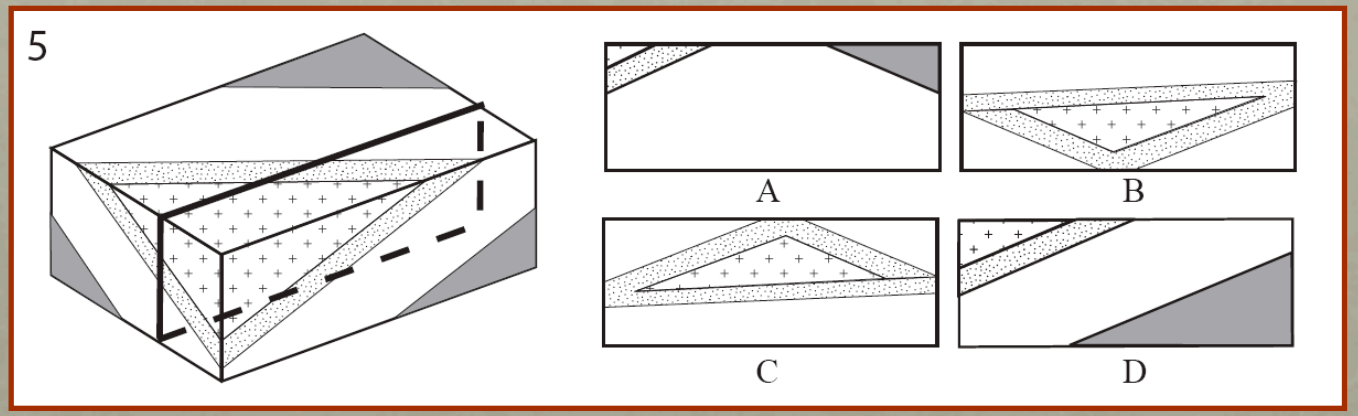


Correlations of Psychometric Tests to Geoscience Tests of Related Tasks

- To what extent do scores on psychometric tests correlate with scores on tests of related geoscience tasks? (If a student excels at penetrative thinking, will she excel at drawing cross-sections through block diagrams? Will the reverse also be true?)





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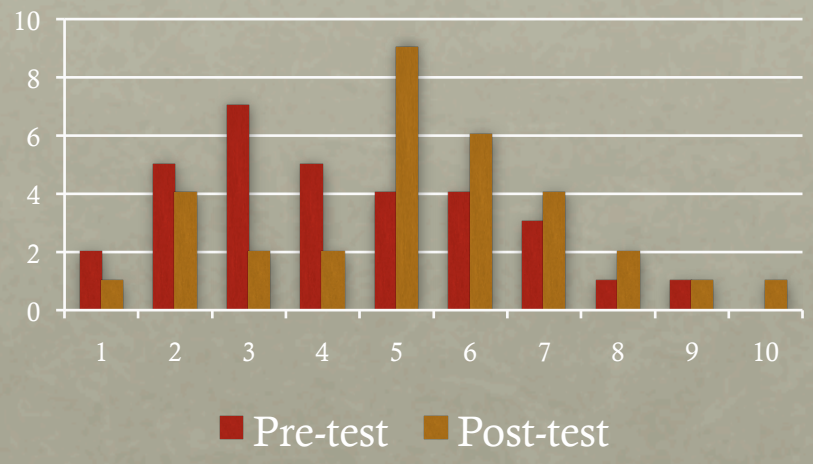
Correlations	PT/block diagrams (N = 32)	MRT/Geo-MRT (N = 32)
R (pre-tests)	0.31	0.58
R^2 (pre-tests)	0.10	0.34
R (post-tests)	0.55	0.33
R^2 (post-tests)	0.31	0.11

Conclusions

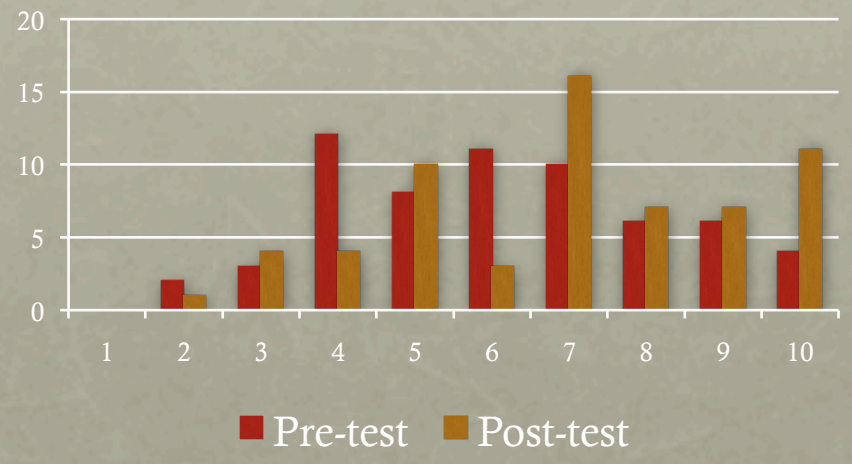
- What spatial skills do students bring to undergraduate geoscience classes?

Students' skills vary from excellent to almost non-existent on measures of several different spatial thinking skills, both in introductory and upper level undergraduate geology courses.

Mental rotation, CC, Intro Geology



Rotation, CC, upper level geology courses

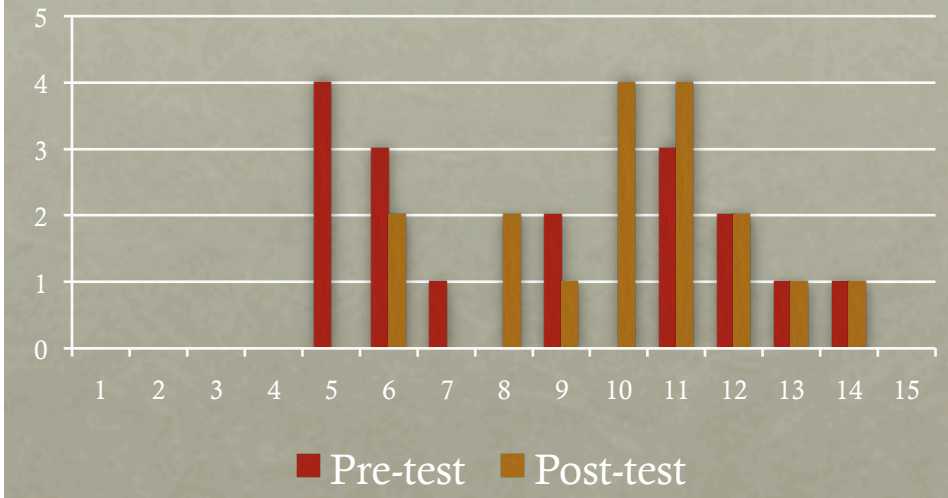


Conclusions

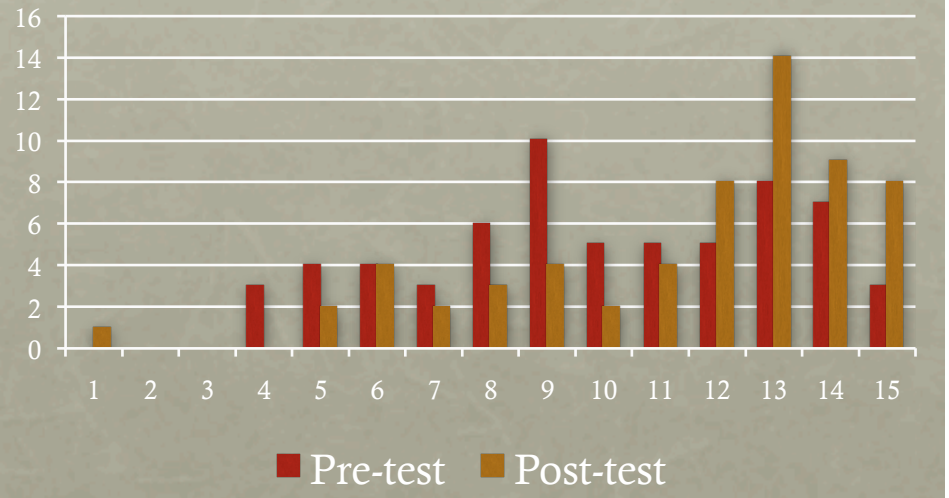
- How do geoscience courses affect students' spatial skills?

On average, students' spatial skills improve only slightly over one term, in both introductory and advanced classes. Presumably, the cumulative effect is significant, though we have not tracked individual students to confirm this hypothesis.

Penetrative thinking, UW-Madison, Structure



Penetrative thinking, CC, upper level



Conclusions

- What are the components of spatial thinking, and to what extent do they correlate? (If a student excels at mental rotation, will she excel at all spatial tasks?)

There are a number of facets to spatial thinking, and while these skills do correlate statistically, an individual student may (for example) excel at mental rotation but be unable to imagine what a slice through the interior of an object would look like.

- Implication: one of our important next steps is identifying the spatial skills essential to geoscience for further study.