Improving Students' Visuo-Penetrative Thinking Skills Through Brief, Weekly Practice

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http://www.spatialintelligence.org

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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

Visuo-Penetrative Thinking

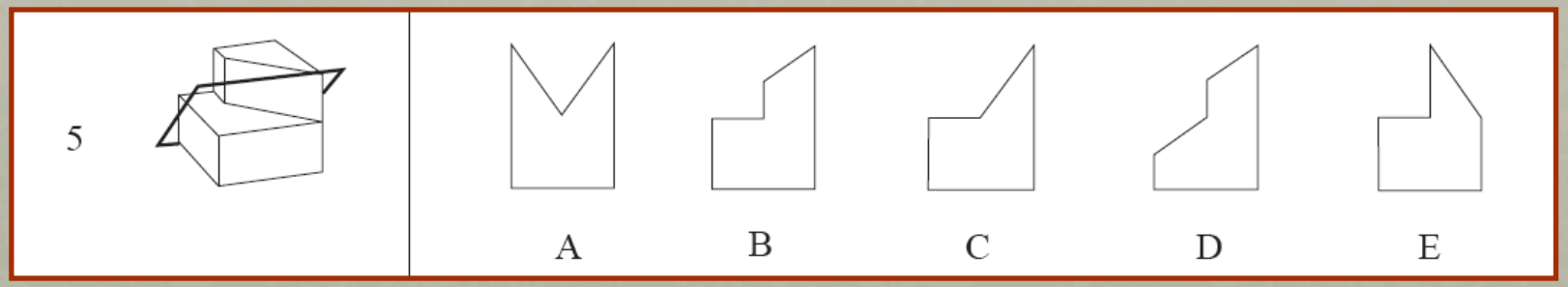
- The ability to imagine (visualize) a slice through an object
- Clearly important in a number of subdisciplines in the geosciences, including structural geology; also has applications in many other STEM disciplines and beyond
- What can we do to improve students' skills in this area? Previous research (e.g. Titus and Horsman, 2009) has shown that practice can be effective.

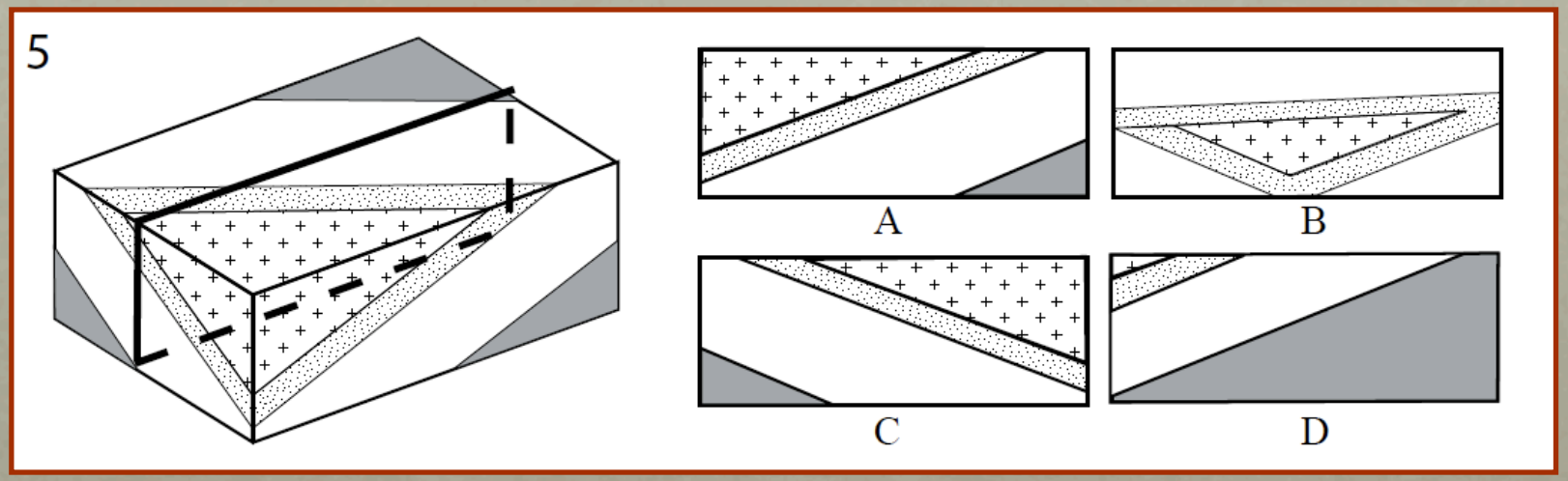
Classroom Study Design

- Structural Geology class at the UW-Madison
- Spring 2010: collect baseline data
  - Pre- and post-tests of students' penetrative thinking, mental rotation, and disembedding skills
- Spring 2011:
  - Same pre- and post-tests of penetrative thinking, mental rotation, and disembedding skills
  - Weekly penetrative thinking exercises at the beginning of lab
    - Designed to take 10-15 minutes
    - Variety of forms (pencil & paper, computer visualizations, play-doh)
    - Geological and non-geological content
    - All required students to sketch one or more cross-sections

Spatial Thinking Tests

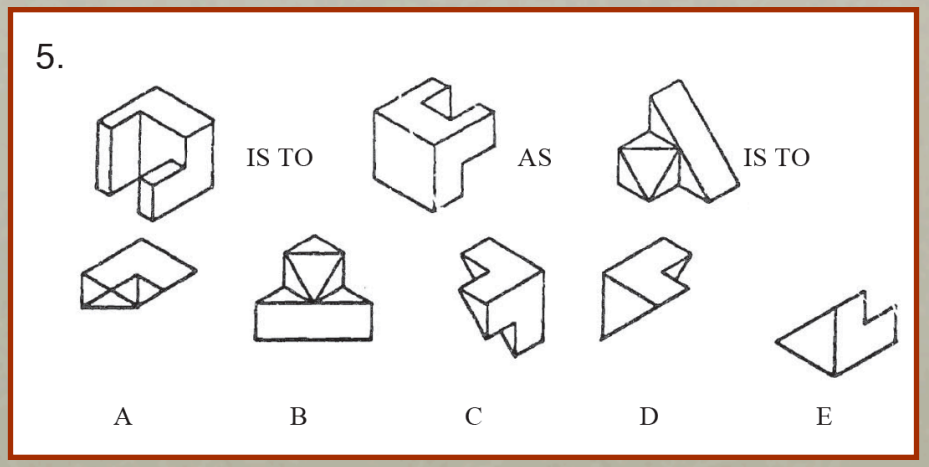
- Pre- and post-tests of students' spatial thinking skills
  - Penetrative thinking (imagining a slice through an object)



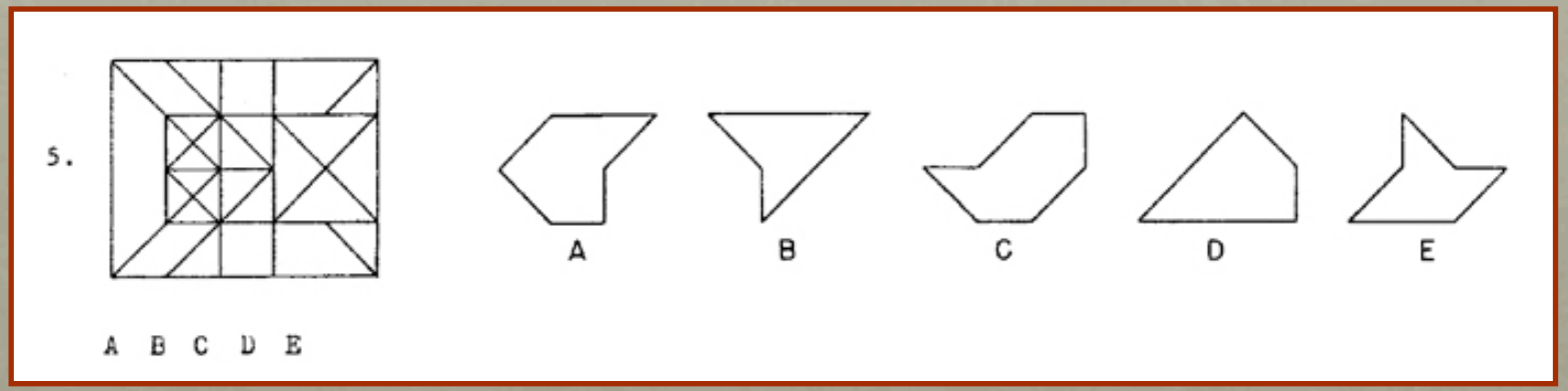


Spatial Thinking Tests

- Pre- and post-tests of students' spatial thinking skills
  - Mental rotation
  - Disembedding *



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



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Confounding Factors

- Things that changed from 2010 to 2011:
  - (Implementation of weekly penetrative thinking exercises)
  - Longer lab periods, and two new lab exercises
  - Different textbook
  - Different TA

Classroom Study Results

- Spring 2010:
  - Students demonstrated a wide range of spatial thinking skills
  - Students showed ***modest improvement*** (on average) on all 3 measures, with ***statistically significant improvement in penetrative thinking***
- Spring 2011:
  - Students demonstrated a wide range of spatial thinking skills
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Weekly Exercises: analog modeling

- Use play-doh to construct a model of
  - An anticline
  - Boudinage
  - Lineation (for example, a stretched pebble conglomerate)
- Slice through your model in several different directions
- Sketch cross-sections parallel, perpendicular, and oblique to the structural grain
- How would your cross-sections be different if the structure (or long axis of the strain ellipsoid) was plunging?

Weekly Exercises: analog modeling

- Construct a model of a faulted fold, like the one illustrated below, using play-doh. Slice the model
  - Parallel to the fold hinge
  - Perpendicular to the fold hinge, through the fault surface
- Sketch the resulting cross-sections
- Investigate similar structures:
  - Faulted syncline
  - Faulted plunging fold

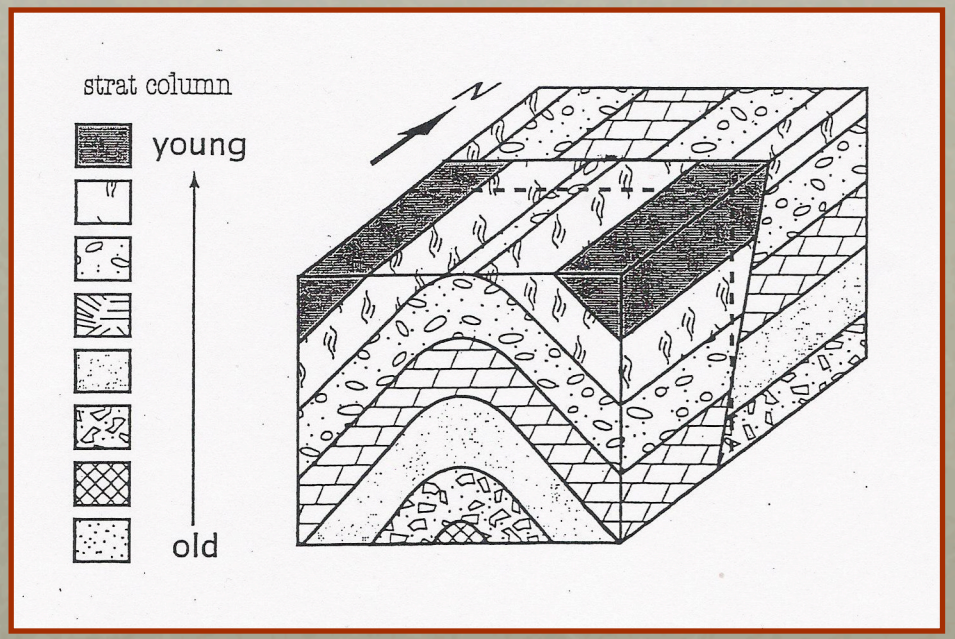
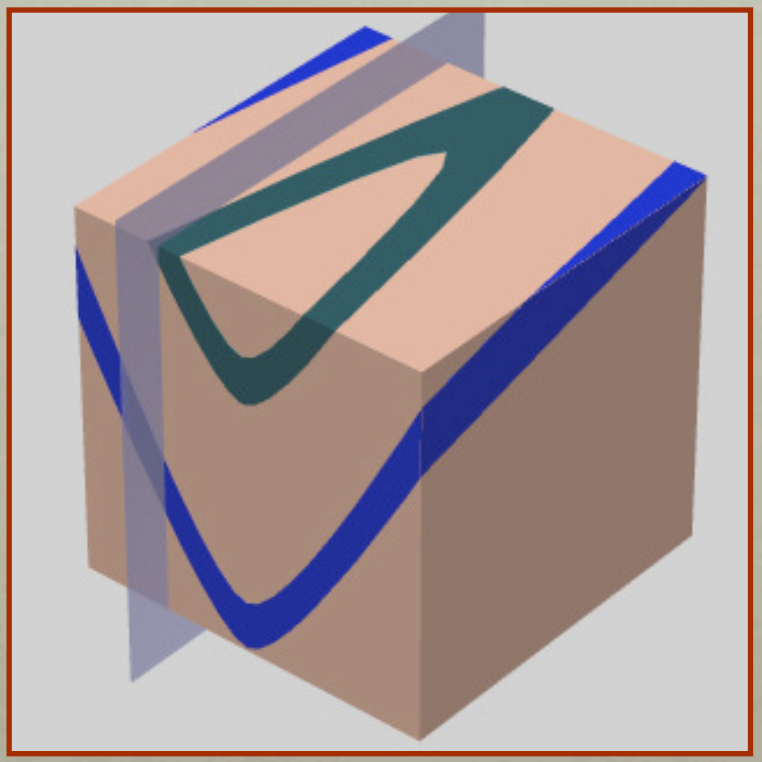
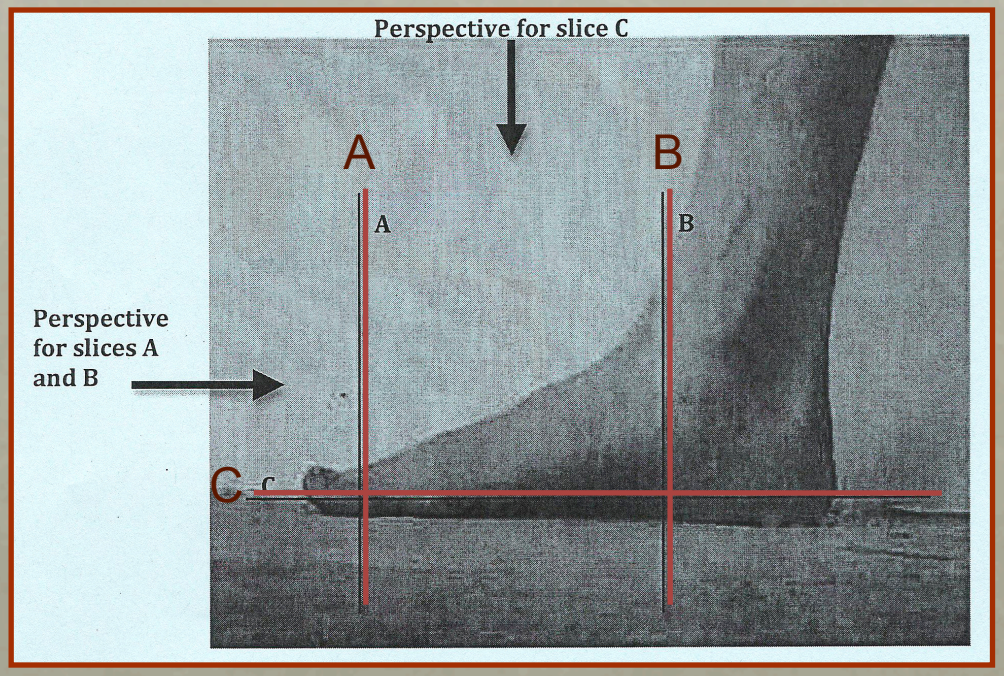


Image by Titus and Horsman

Weekly Exercises: computer visualizations

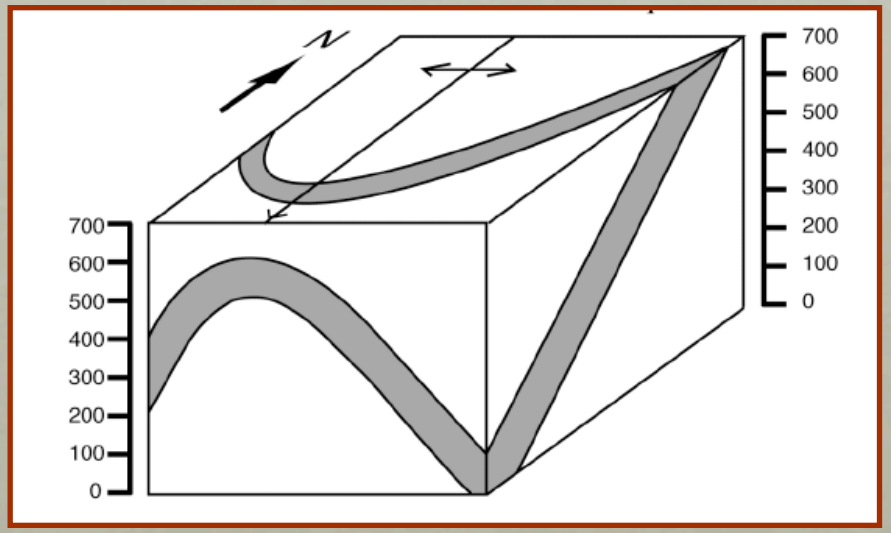
- Sketch a cross-section for the slicing plane indicated, as viewed from the right side of the block
- Sketch the 3 cross-sections of a human foot indicated in the diagram below



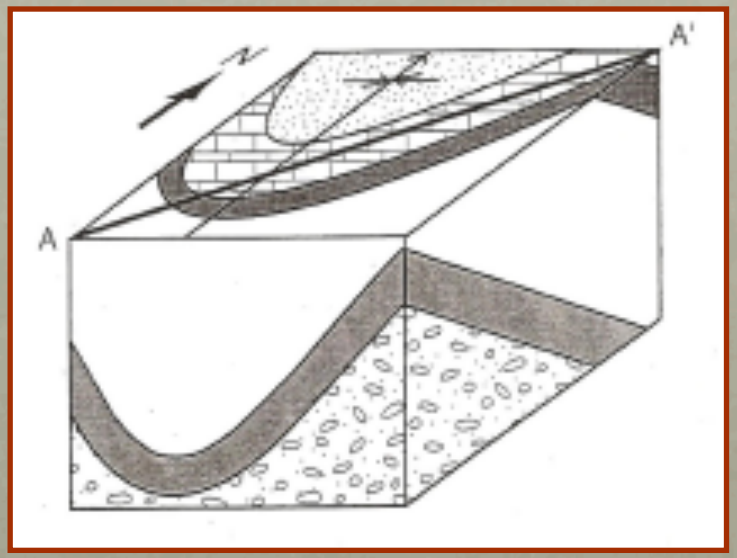


Weekly Exercises: thought exercises

- Construct a structure contour map for the top of the gray unit, using 100m contour intervals; describe the orientation of this structure and the structure contour lines in words



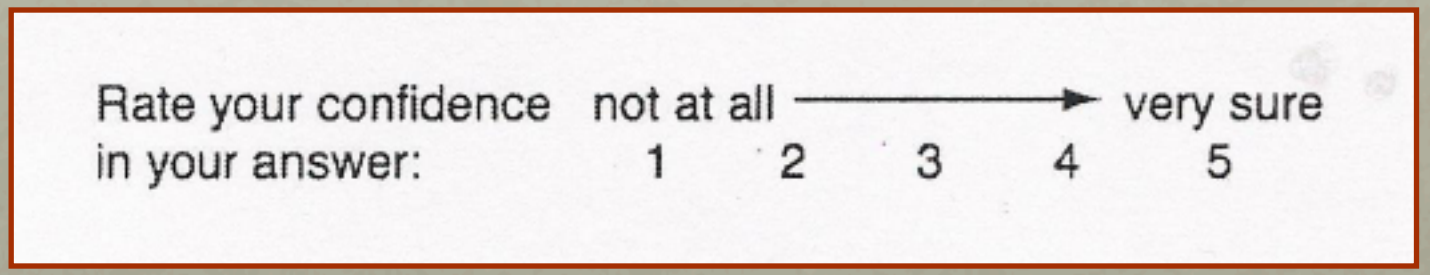
- Sketch a cross-section from A-A'



Images & exercises by Titus and Horsman

Weekly Exercises: metacognitive component

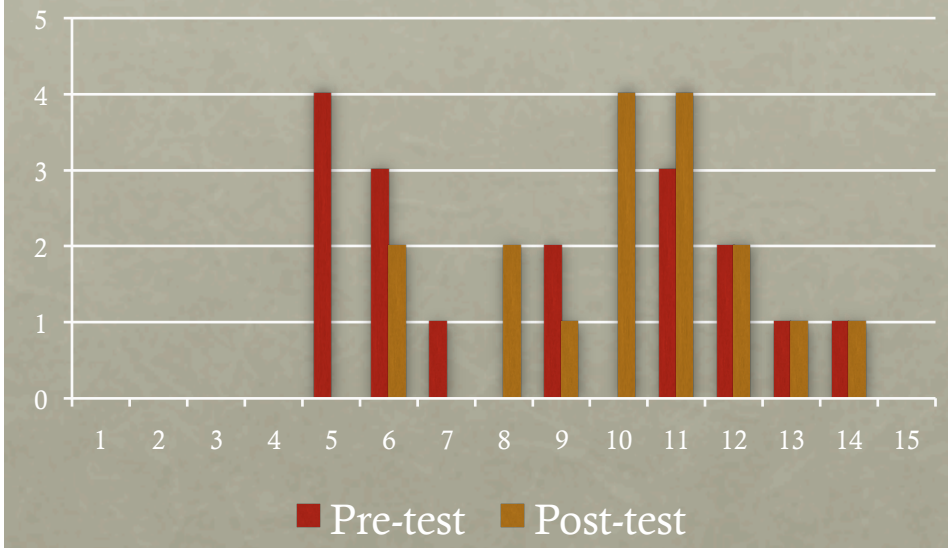
- Metacognition: thinking about thinking, thinking about learning
- Research demonstrates that students who engage in metacognition are able to monitor, regulate, and (therefore) improve their learning (NRC, 2000; see SERC's website on the role of metacognition in learning for more information)



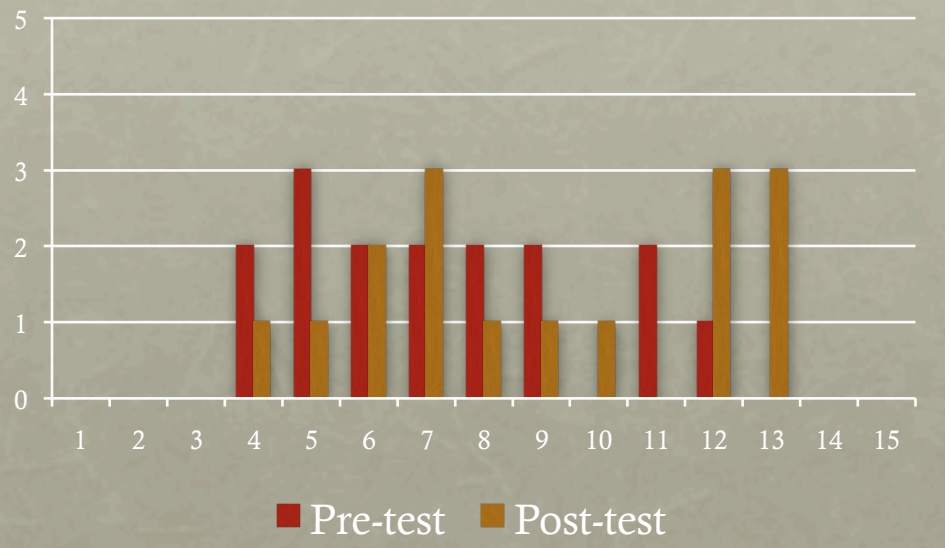
Results: Penetrative Thinking (ETS planes of reference)

	Pre-test	Post-test	Gain	T-test
2010 (N=17)	8.6 (3.2)	10.1 (2.2)	1.5 (2.6)	0.03
2011 (N=16)	7.3 (2.5)	9.0 (3.1)	1.7 (2.2)	0.01

UW-Madison, Structure, Spring 2010



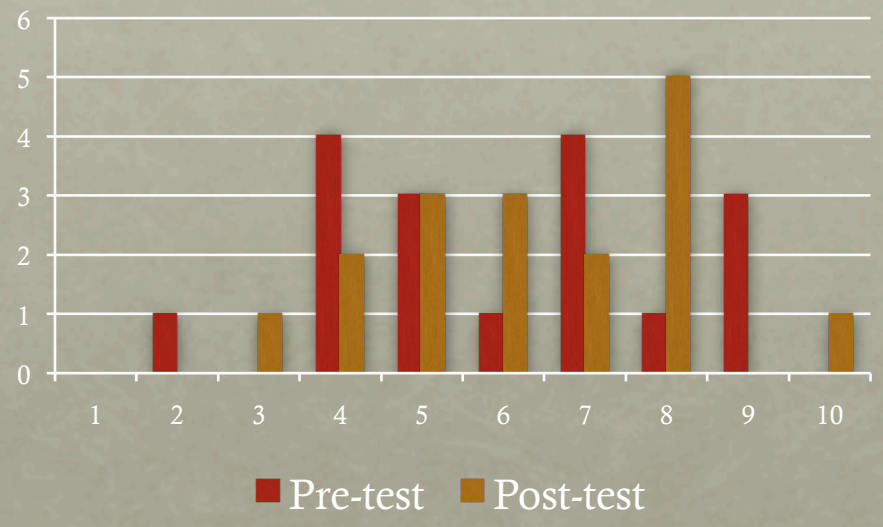
UW-Madison, Structure, Spring 2011



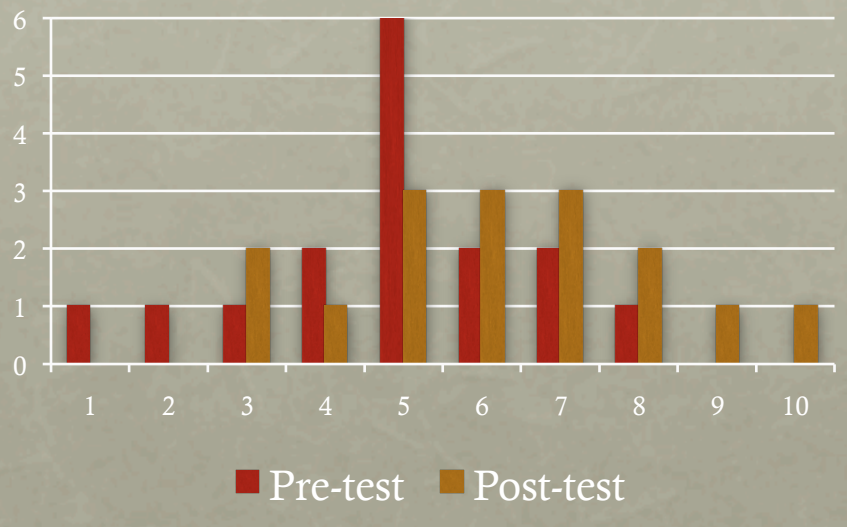
Results: Mental Rotation (PVRT)

	Pre-test	Post-test	Gain	T-test
2010	6.0 (2.1)	6.4 (1.9)	0.4 (2.0)	0.48
2011	4.9 (1.8)	6.2 (2.0)	1.3 (1.5)	0.00

UW-Madison, Structure, Spring 2010



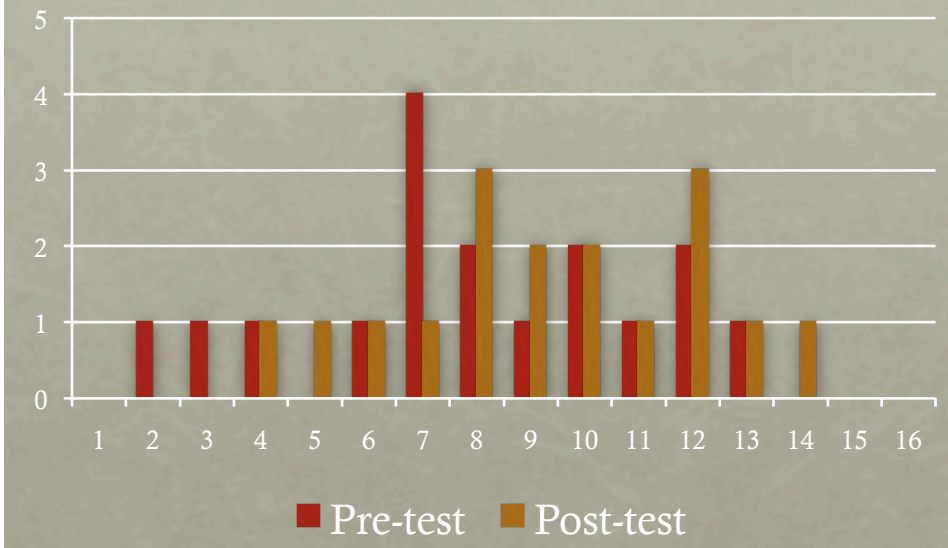
UW-Madison, Structure, Spring 2011



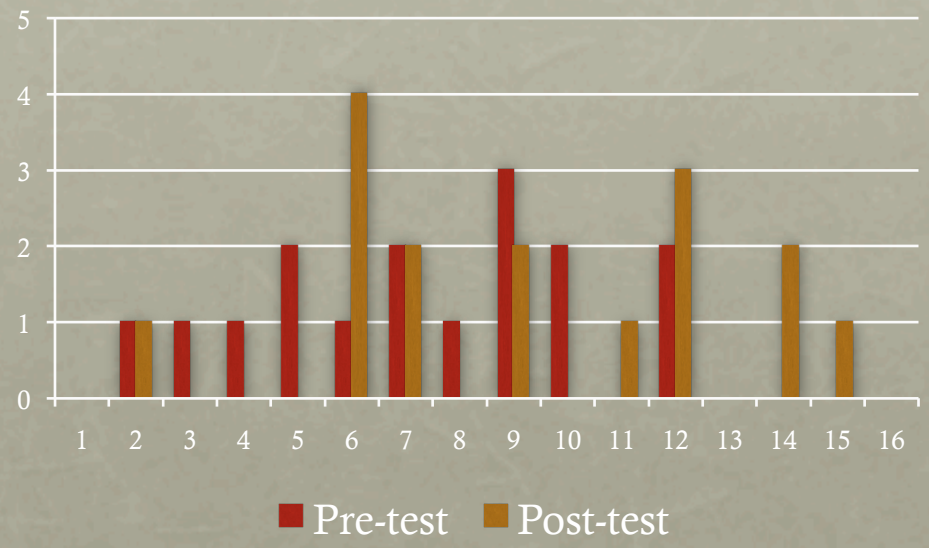
Results: Disembedding (ETS hidden figures)

	Pre-test	Post-test	Gain	T-test
2010	8.0 (3.2)	9.3 (2.8)	1.3 (3.3)	0.12
2011	7.4 (3.0)	9.3 (3.7)	1.9 (2.8)	0.02

UW-Madison, Structure, Spring 2010



UW-Madison, Structure, Spring 2011



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Conclusions

- Students' (even Geology majors) skills vary from excellent to almost non-existent on measures of several different spatial thinking skills
- These skills do improve over the course of a semester
- Focused weekly practice, even for only 10-15 minutes, can make a difference in the amount of improvement
- Interventions focused on strengthening penetrative thinking may also help develop other aspects of spatial thinking