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
The ability to imagine (visualize) a slice through an object is clearly important in a number of subdisciplines in the geosciences, including structural geology. It 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
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 mental rotation, penetrative thinking, 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
  - Almost all required students to sketch one or more cross-sections
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
  • Students showed *greater average gains* on all 3 measures, and *all gains were statistically significant*
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)

Rate your confidence in your answer: 1 not at all 2 3 4 very sure 5
Results: Penetrative Thinking (ETS planes of reference)

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<th>Pre-test</th>
<th>Post-test</th>
<th>Gain</th>
<th>T-test</th>
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UW-Madison, Structure, Spring 2010

UW-Madison, Structure, Spring 2011
Results: Mental Rotation (PVRT)

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UW-Madison, Structure, Spring 2010

UW-Madison, Structure, Spring 2011
## Results: Disembedding
(ETS hidden figures)

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<tbody>
<tr>
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</tbody>
</table>

UW-Madison, Structure, Spring 2010

UW-Madison, Structure, Spring 2011
Classroom Study Results

• Spring 2010:
  • Students demonstrated a wide range of spatial thinking skills
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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