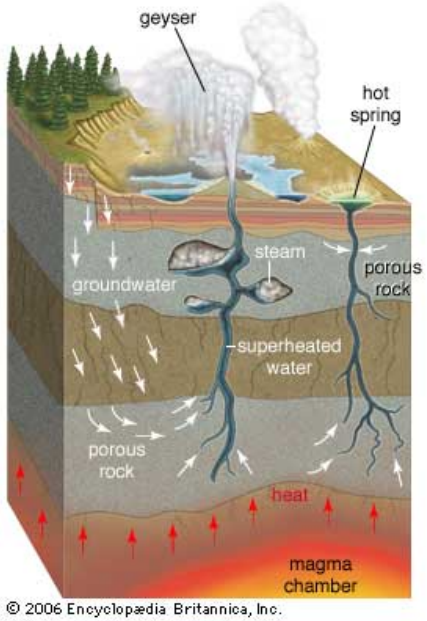
Teaching Penetrative Thinking Via Progressive Alignment and Directed Sketching

Kristin M. Gagnier, Kinnari Atit, Carol Ormand & Thomas F. Shipley

Spatial Intelligence and Learning Center
Temple University

- The inside is critical!

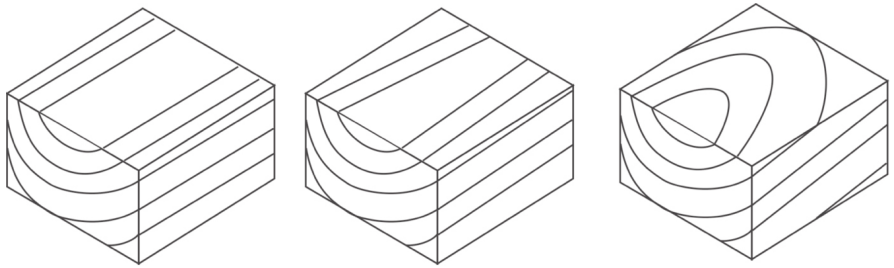


- *Penetrative thinking* (Kali & Orion, 1996) is challenging
- What cognitive challenges do students face?
- Teaching penetrative thinking using
  - Two teaching strategies that facilitate spatial reasoning
    - Spatial Analogy (Gentner et al. 1993, Christie & Gentner , 2010)
    - Sketching (Jee et al, 2009; Johnson & Reynolds, 2005)

SILC

NSF

- Spatial Alignment
  - Comparison promotes learning by highlighting common relational structure

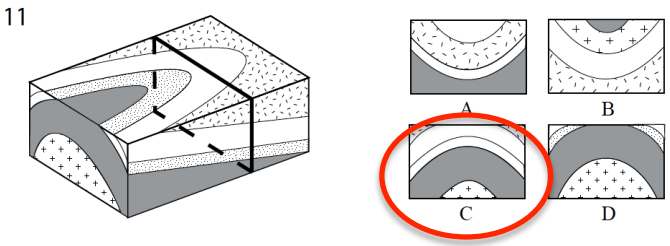


  - Learning aided by high similarity comparisons progressing to low similarity comparisons (Kotovsky & Gentner, 1996)

- Sketching
  - Assisting in the building of a spatial representation (Ainsworth et al, 2011) and focusing attention on spatial relationships (Gorbet & Clement, 1999)
  - Directed sketching influence spatial skills in engineering (Sorby, 2009; Mohler & Miller, 2008)
  - Indicator of content knowledge (Jee et al., 2009; Matlen et al., 2012; Turner & Libarkin, in press)

Can Alignment & Sketching Improve PT?

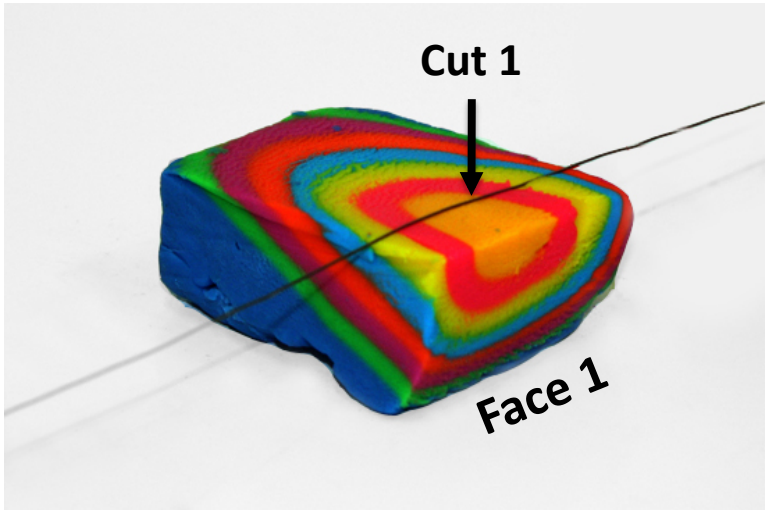
- Sixty-two Psychology undergraduates Pre and Post GBST (Ormand et al, 2011)



- Viewed powerpoint of slices into block diagrams

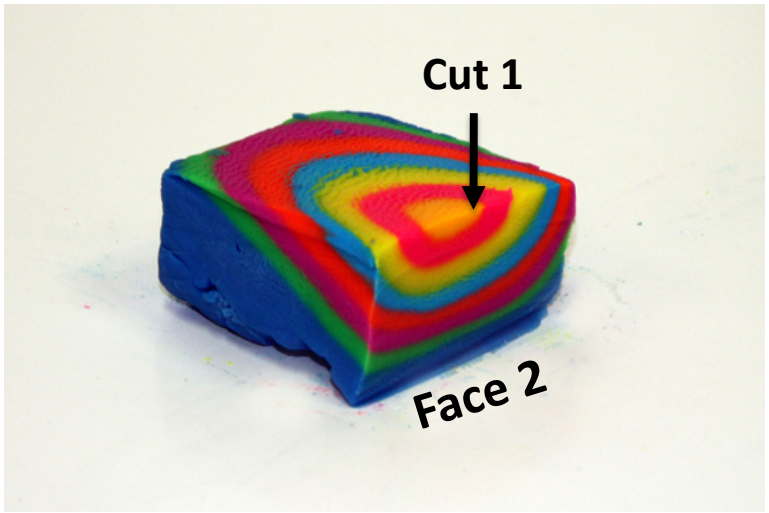
- Experimental Condition (N=31): Three progressive slices and sketched the cross-section

Experimental Condition

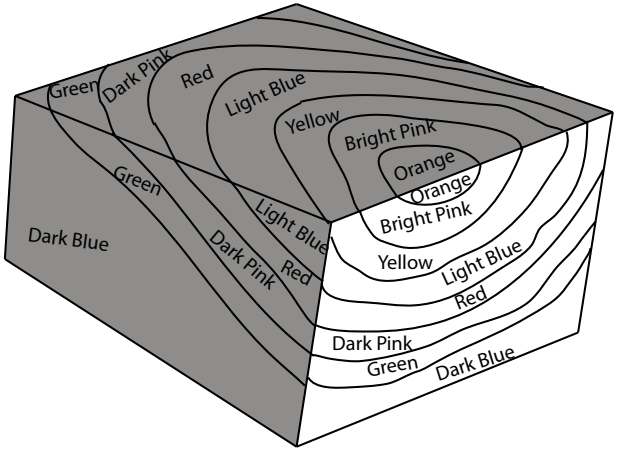


Diagrams based work by Kali & Orion (1996) and diagrams by Steven Reynolds

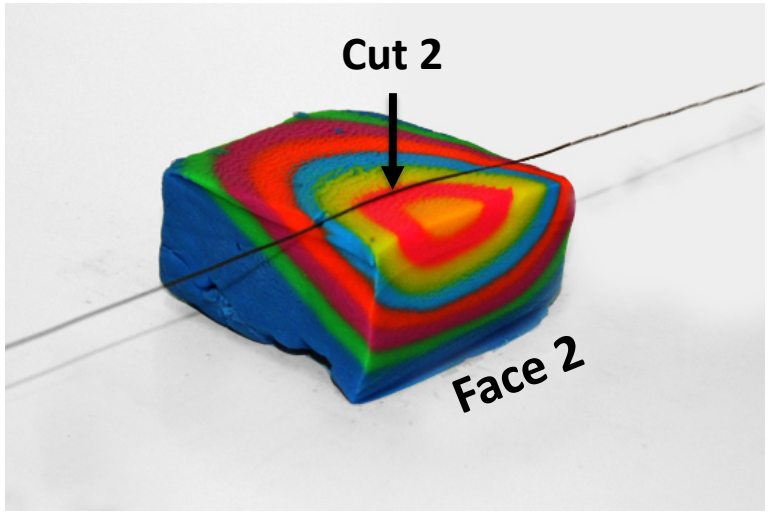
1. Sketch Cross-section produced by Cut 1
2. Explain how you used layers visible on top, face and perpendicular side to predict cross-section



Compare your sketch with correct

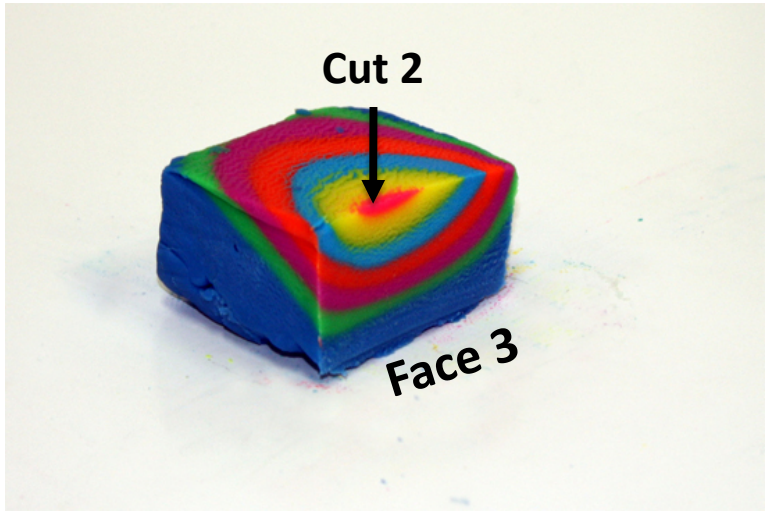


Experimental Condition

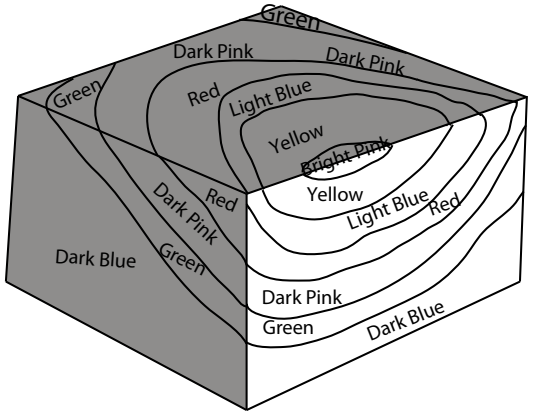


Diagrams based work by Kali & Orion (1996) and diagrams by Steven Reynolds

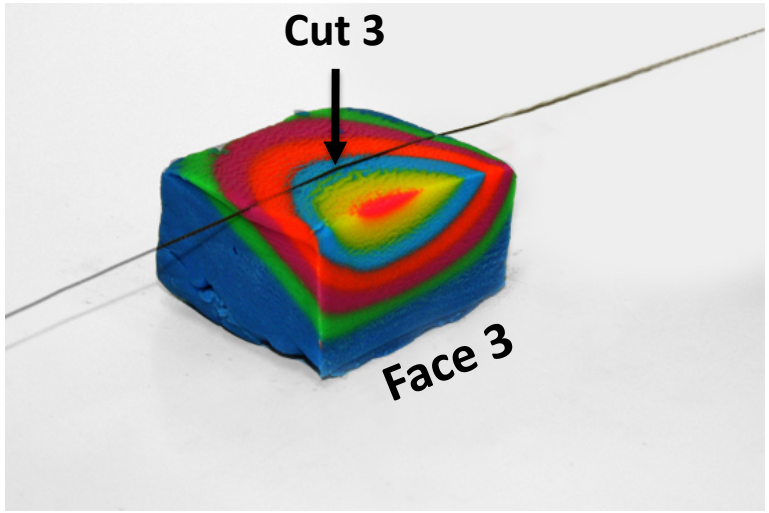
1. Sketch Cross-section produced by Cut 1
2. Explain how you used layers visible on top, face and perpendicular side to predict cross-section



Compare your sketch with correct

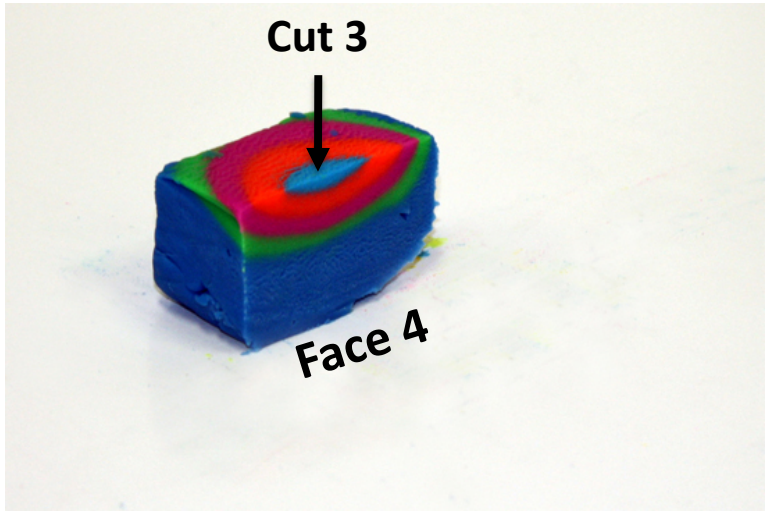


Experimental Condition

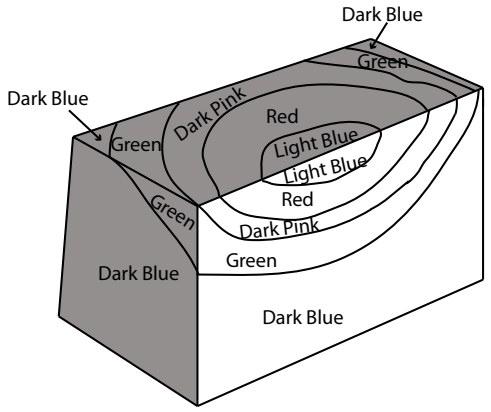


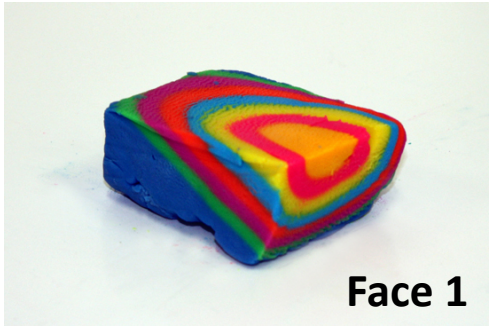
Diagrams based work by Kali & Orion (1996) and diagrams by Steven Reynolds

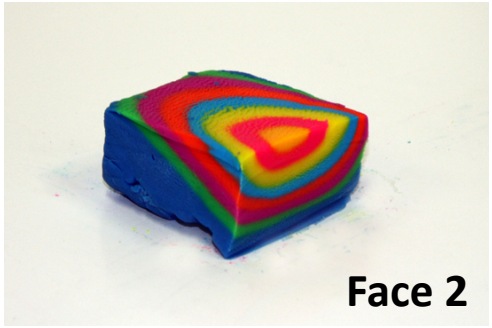
1. Sketch Cross-section produced by Cut 1
2. Explain how you used layers visible on top, face and perpendicular side to predict cross-section

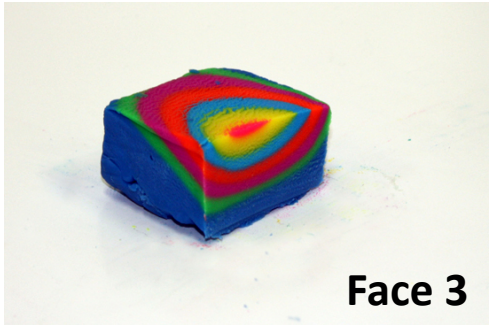


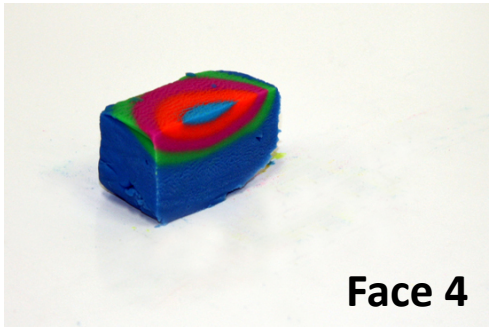
Compare your sketch with correct



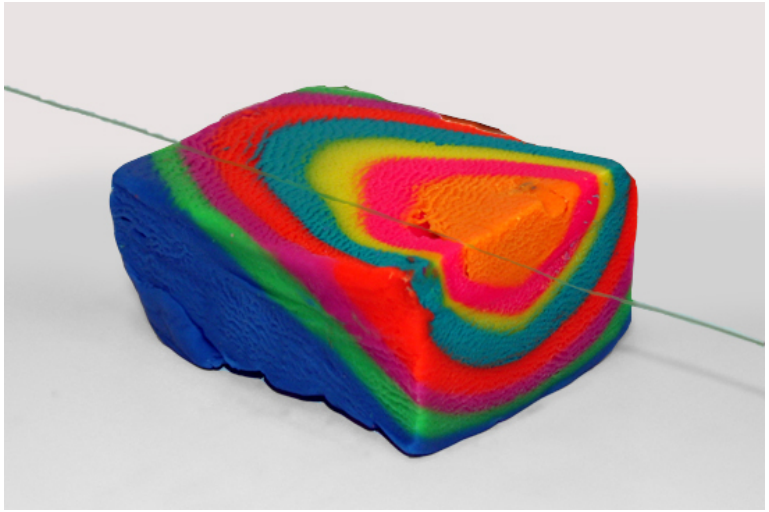




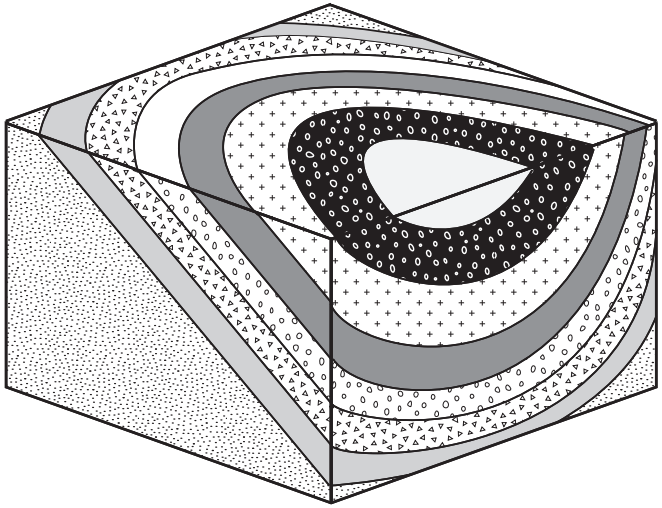




Playdoh Model cut other way



Outline Drawing Version cut both ways



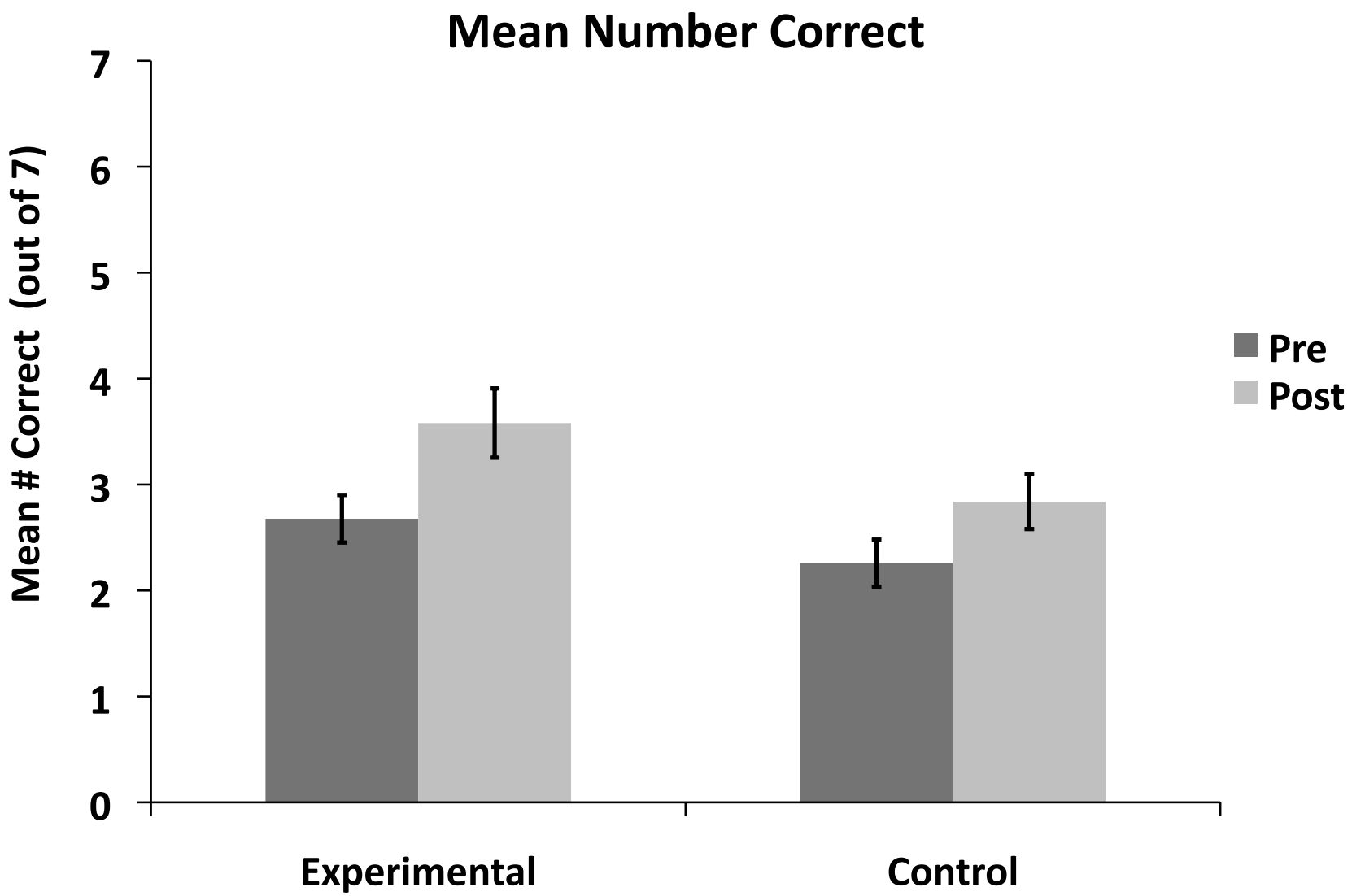
Control Condition

- Viewed same pictures
- Estimated amount of paint it would take to paint sides and explained why
- Sketched visible diagram

Prediction

If alignment and sketching facilitate PT

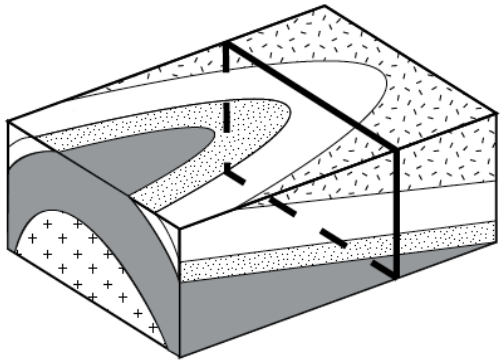
- Significant pre to post improvement in experimental condition
- Sketching performance predicts post test score

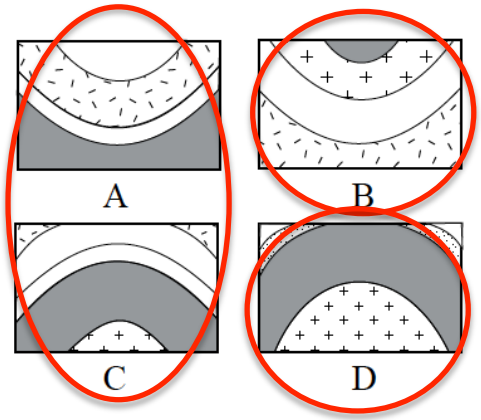


- Significant improvement from pre to post, $p<.01$
- Effect of condition, $p<.05$
- No interaction

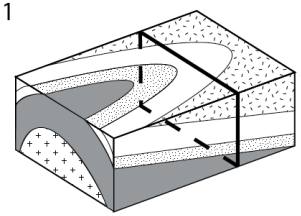
Penetrative Choices (Kali & Orion, 1996)

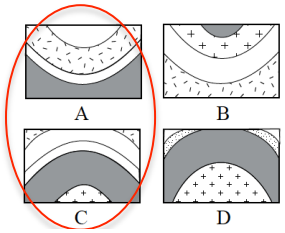
11



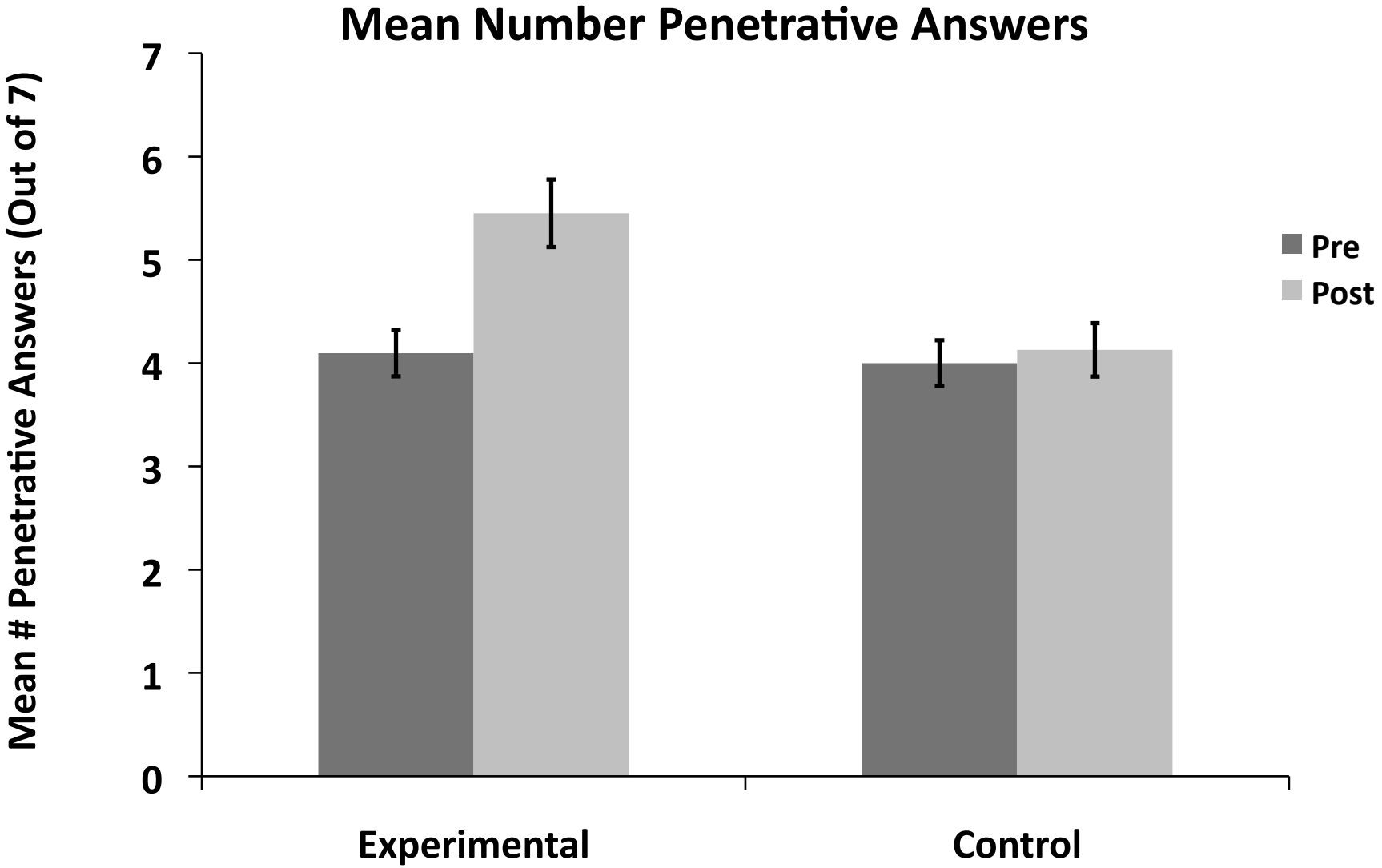


Pick A or C: Recognize inside of 3D structure is consistent with top

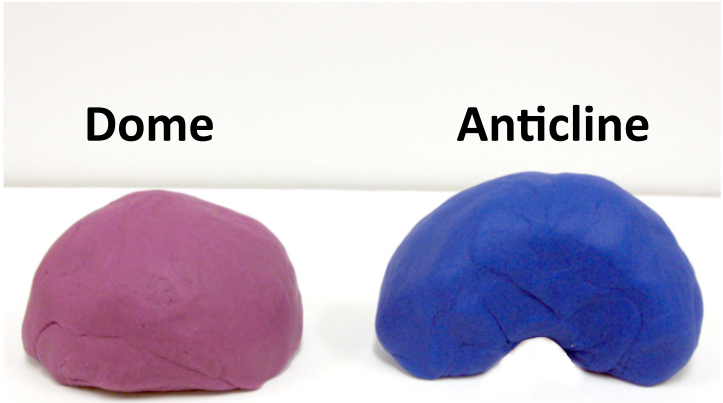




- Improvement from pre to post, p<.01
- Effect of condition, p<.01
- Significant interaction, p<.01



Transfer to 3D Model?



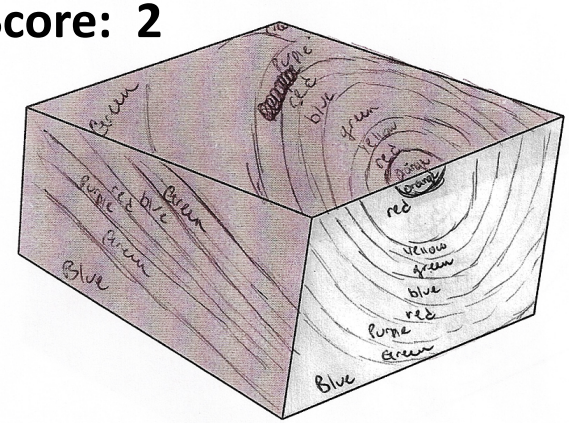
Percent who choose dome?

- 40% in Experimental
- 22% in Control

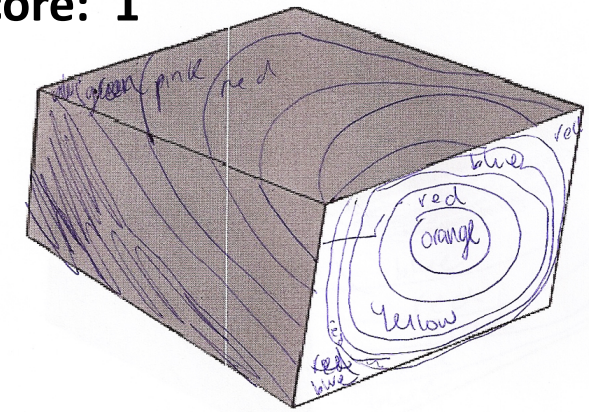
Sketch Accuracy & Performance

1. Shape of layers in cross-section
2. Shape of layers on side and top
3. Coordination of Layers

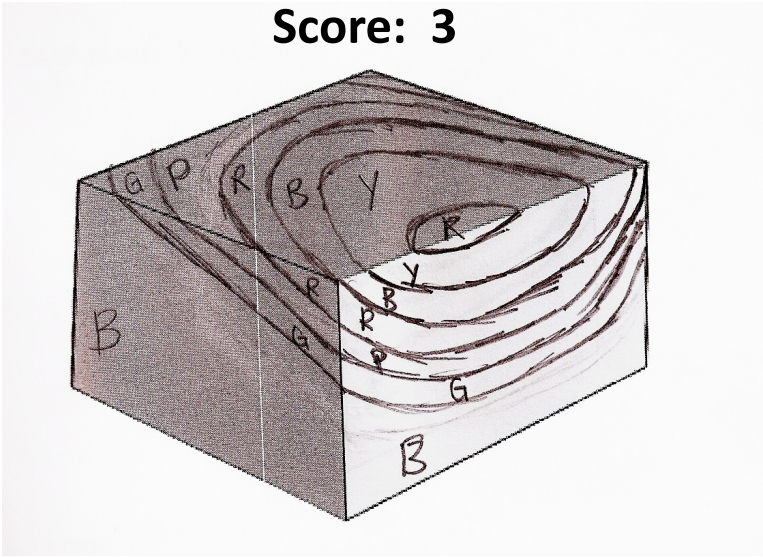
Score: 2



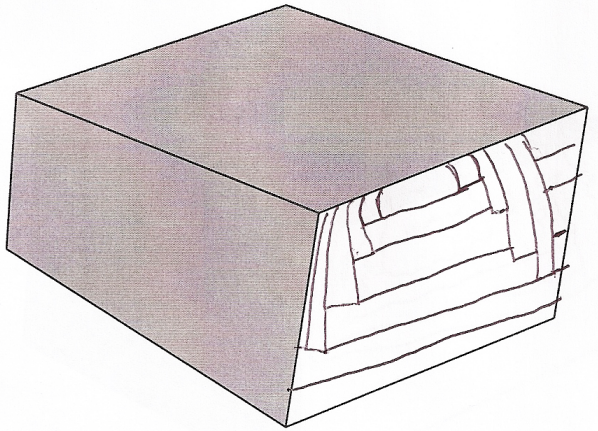
Score: 1



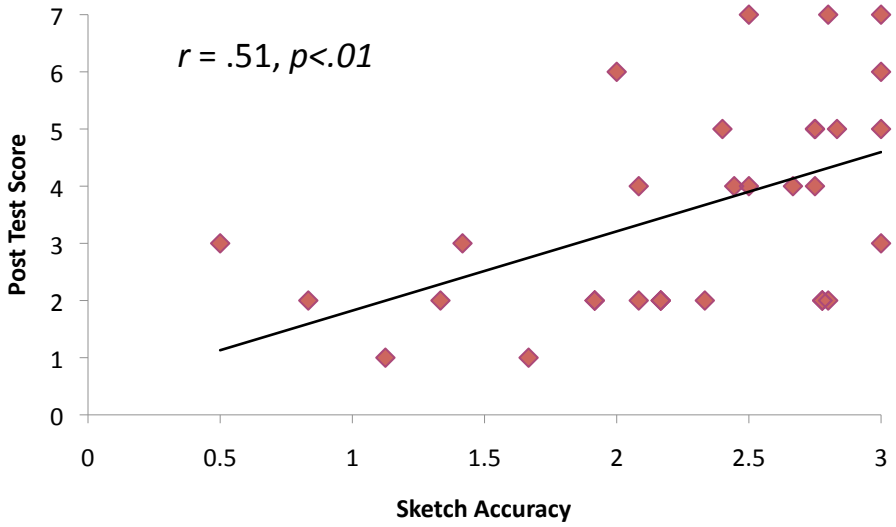
Score: 3

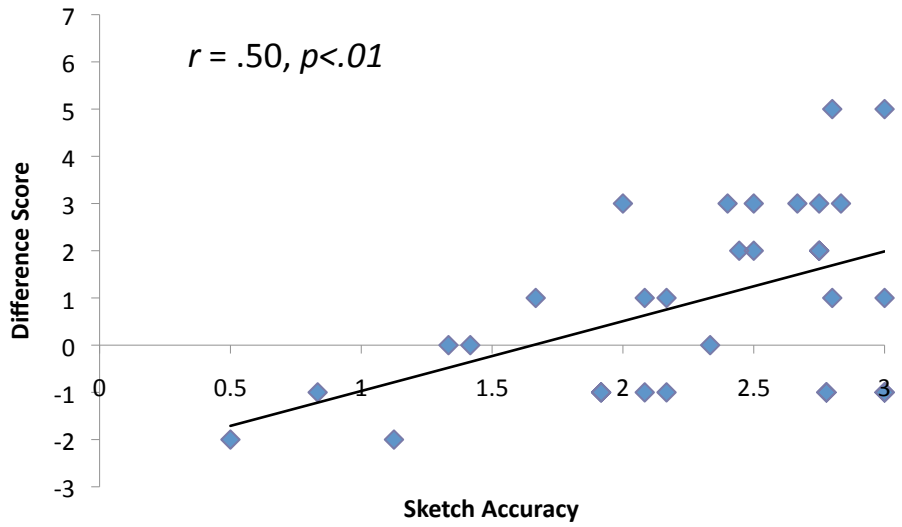


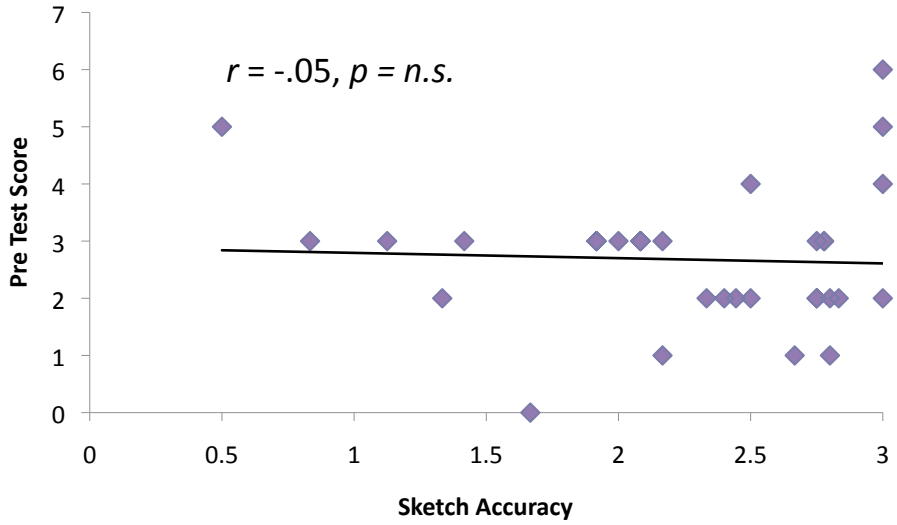
Score: 0



Sketch Accuracy is out of 3







If students are learning through sketching then

- First sketch does not predict post test or improvement
- Last sketch does predict post test score or improvement

Performance on Post Test

- First Sketch: r = .24, *p=n.s.*
- Last Sketch: r = .41, *p=.02*

Improvement from Pre test to Post Test

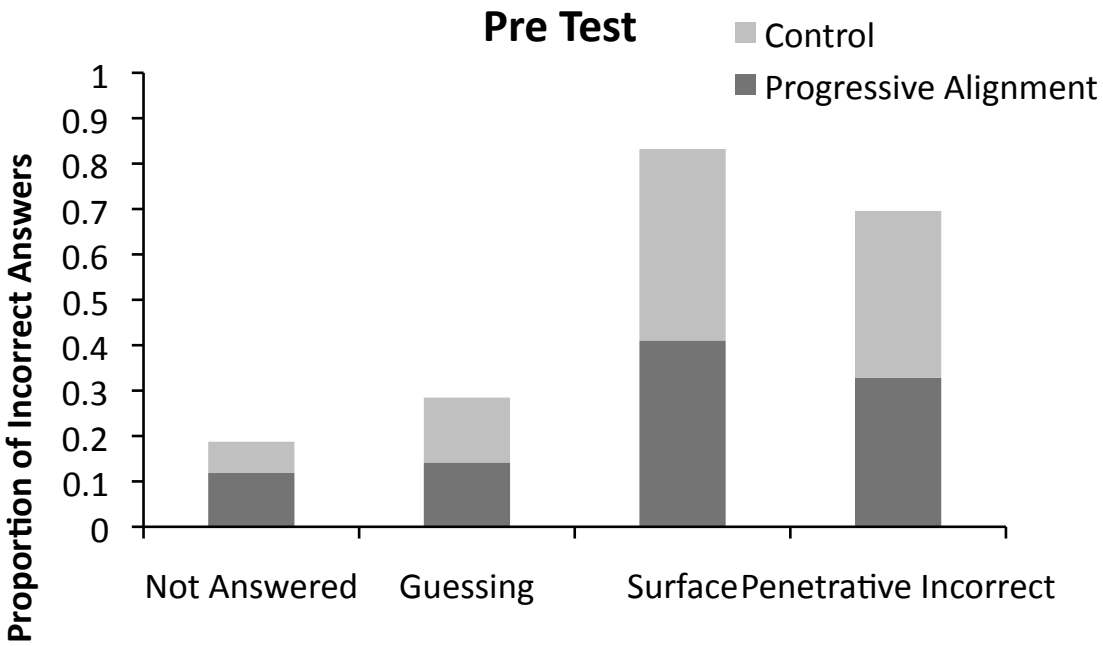
- First Sketch: r = .20, *p=n.s.*
- Last Sketch: r = .46, *p=.02*

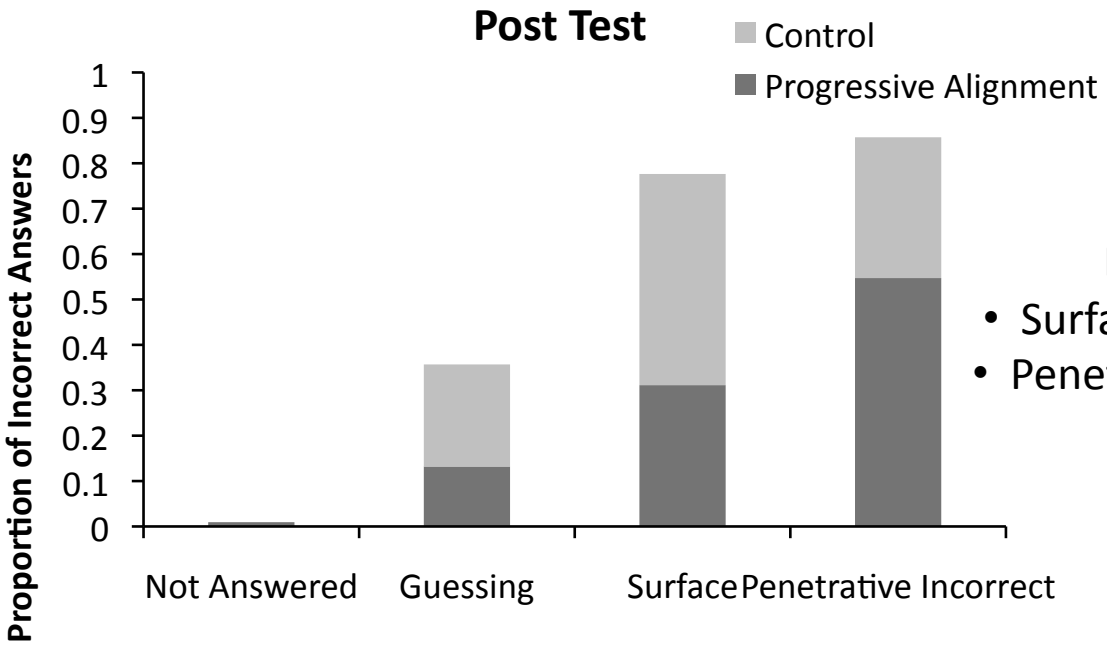
Summary

- Spatial alignment and sketching improve penetrative thinking
- Transfer to a 3D model
- Quality of sketch predicted post test score and gains
- Data suggest that alignment and sketching facilitate penetrative thinking

Thank you!

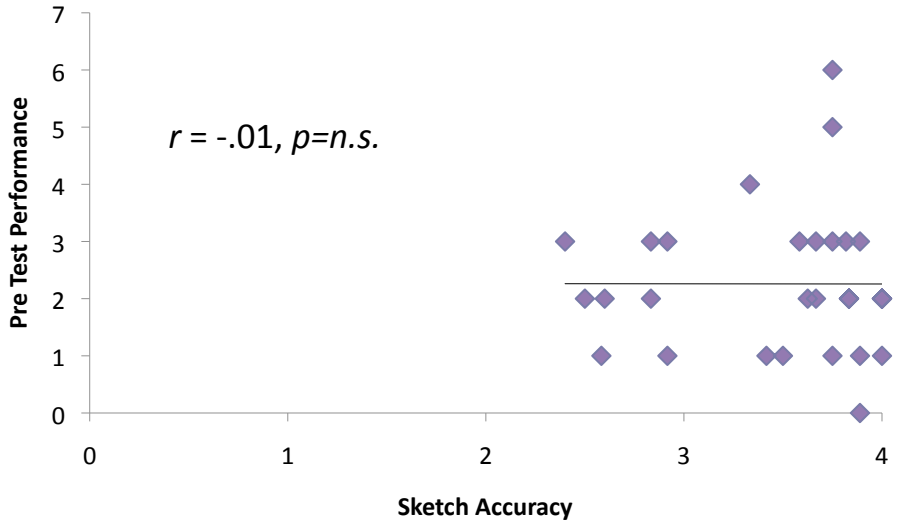
Comments/Questions

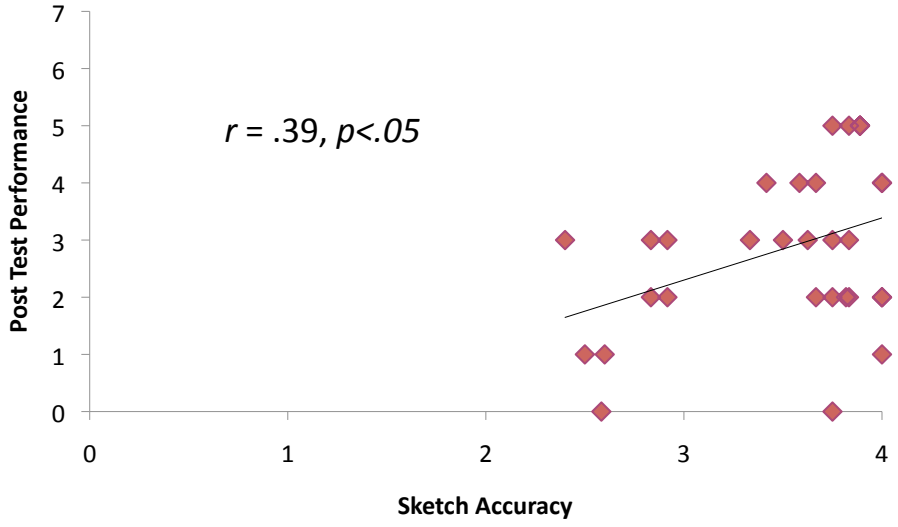


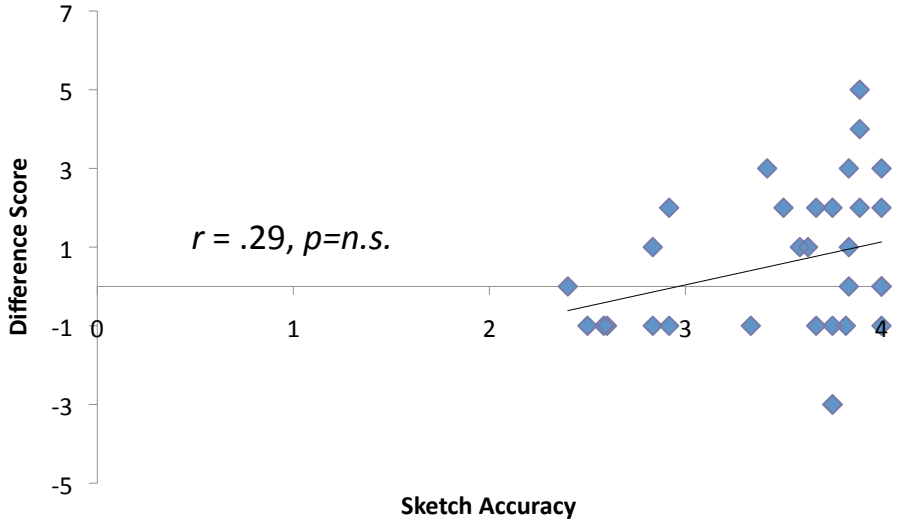


PA Condition:

- Surface Choices go down
- Penetrative Choices go up







Sketches that predict Post Test

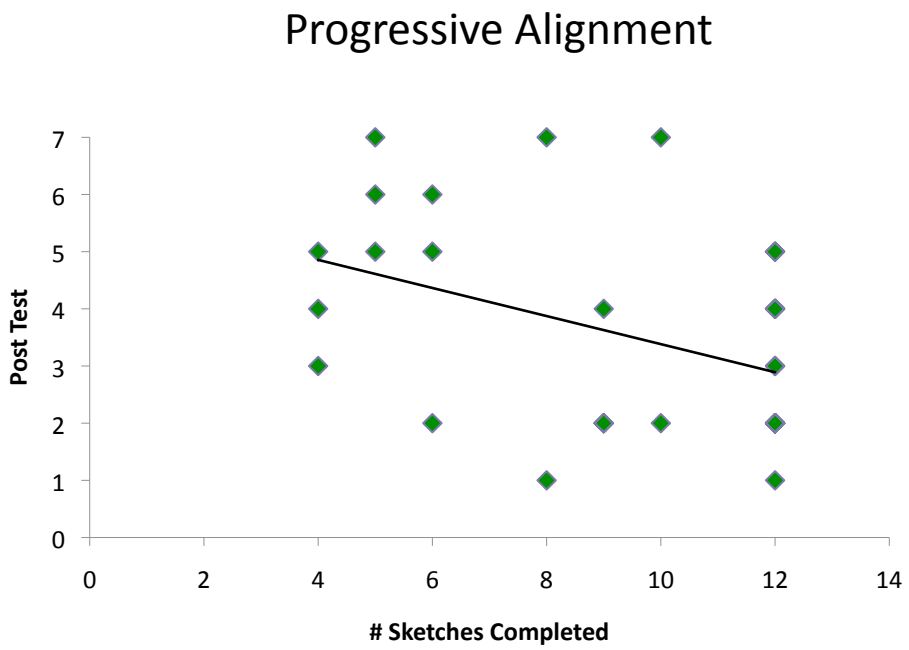
First sketch: p=.78

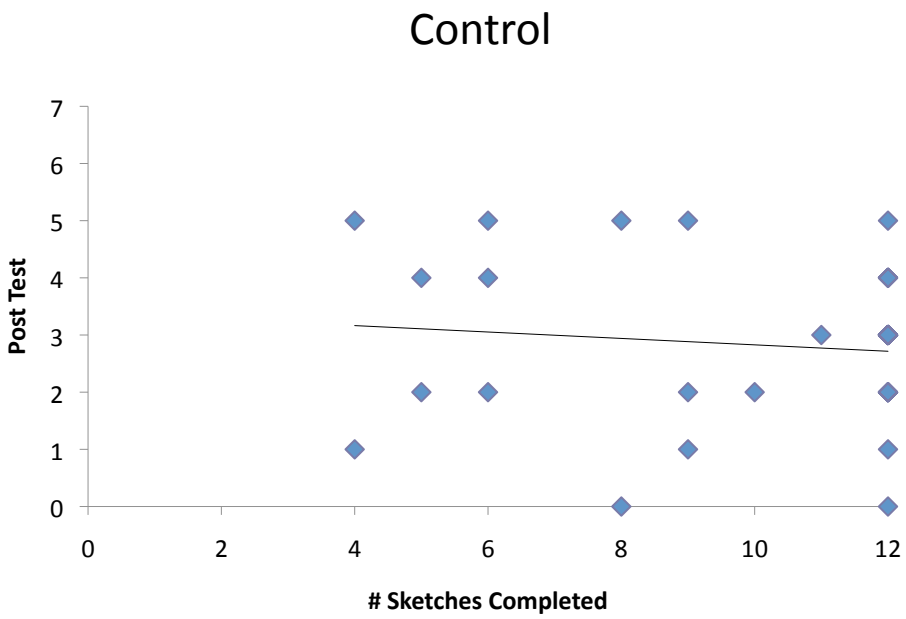
Last sketch: p=.99

Difference Score

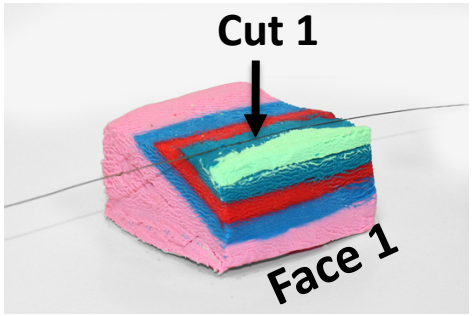
First sketch: p= .89

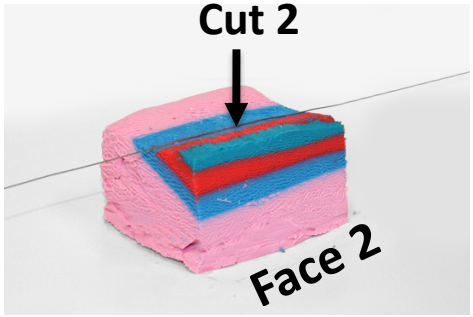
Last sketch: p=.75

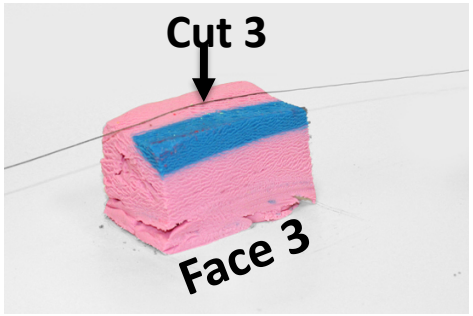

Progressive Alignment
Post Test
Sketches Completed
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12
14


Control
Post Test
Sketches Completed
0
1
2
3
4
5
6
7
0
2
4
6
8
10
12

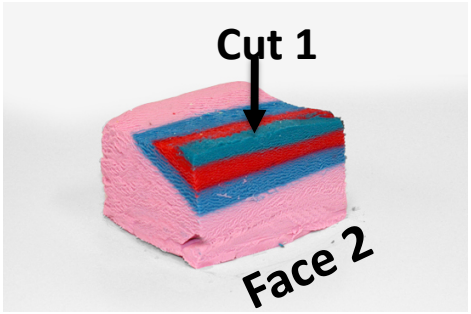
What drove this effect?



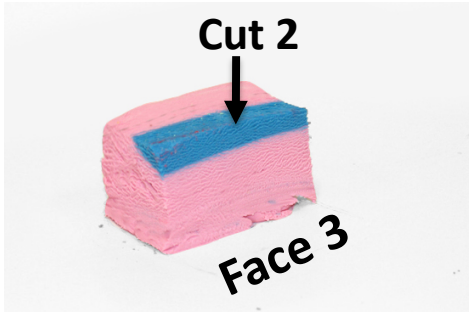




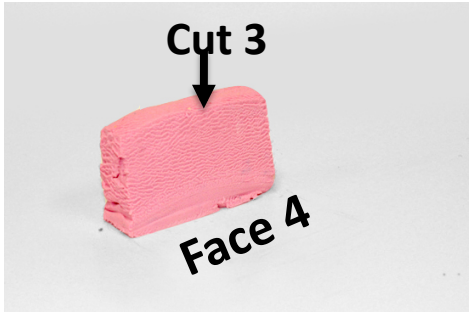
CROSS-SECTION



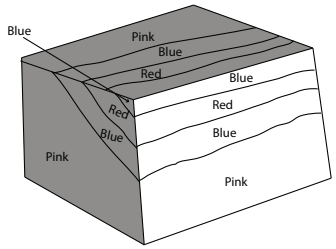
CROSS-SECTION



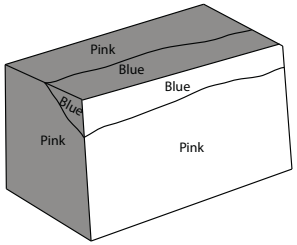
CROSS-SECTION



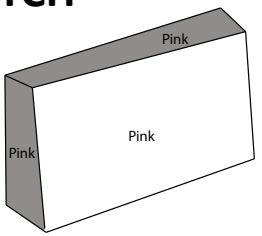
SKETCH

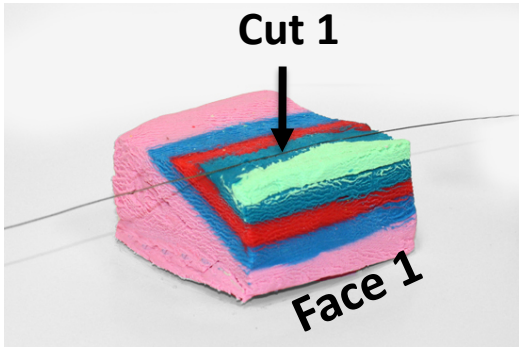


SKETCH

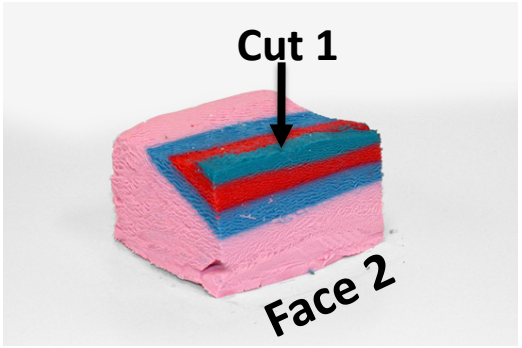


SKETCH

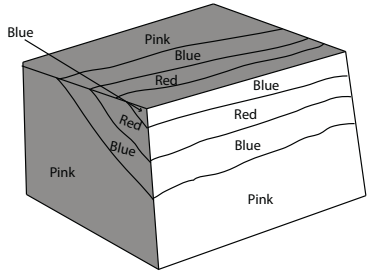


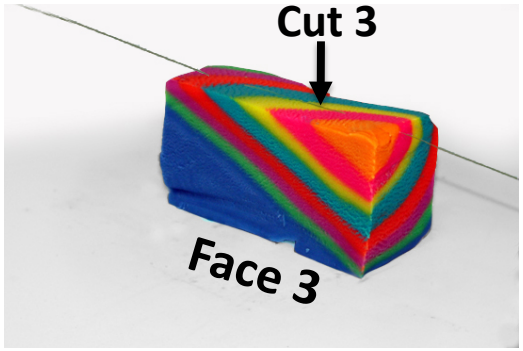


CROSS-SECTION

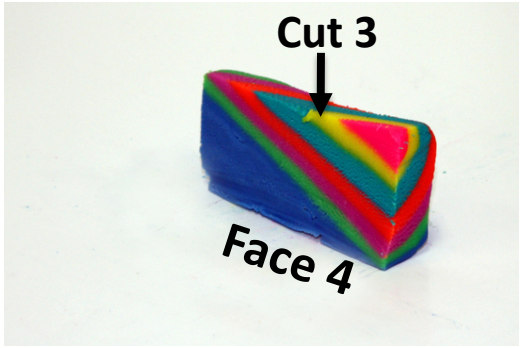


SKETCH

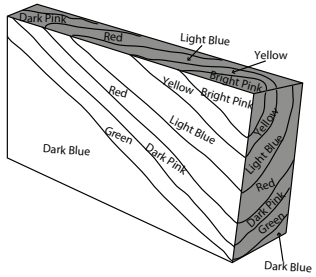


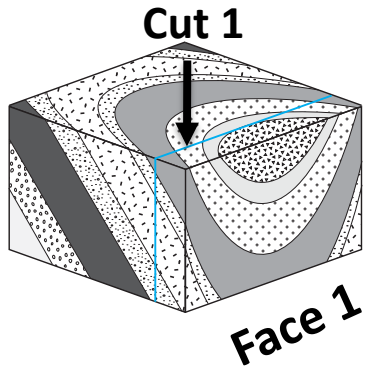


CROSS-SECTION

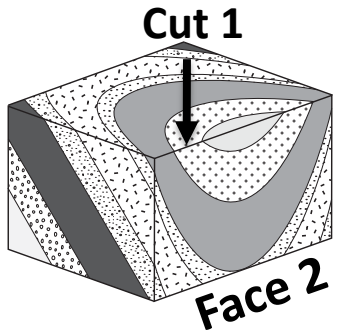


SKETCH





CROSS-SECTION



SKETCH