Teaching Penetrative Thinking Via Progressive Alignment and Directed Sketching

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• 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)
• 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

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

Pick A or C: Recognize inside of 3D structure is consistent with top
Mean Number Penetrative Answers

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

### Mean Penetrative Answers (Out of 7)

<table>
<thead>
<tr>
<th></th>
<th>Experimental</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre</td>
<td>4.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Post</td>
<td>6.0</td>
<td>4.0</td>
</tr>
</tbody>
</table>

**Graph**:}

- Y-axis: Mean # Penetrative Answers (Out of 7)
- X-axis: Experimental vs. Control
- Bars show mean with error bars for pre and post conditions.

**Legend**:
- Pre
- Post
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: 3

Score: 2

Score: 1

Score: 0
Sketch Accuracy is out of 3

\[ r = .51, p<.01 \]

\[ r = .50, p<.01 \]

\[ r = -.05, p = n.s. \]
If students are learning through sketching then

- **First skin** does not predict post test or improvement

- **Last skin** does predict post test score or improvement
Performance on Post Test

- First Sketch: $r = 0.24$, $p=n.s.$
- Last Sketch: $r = 0.41$, $p=0.02$

Improvement from Pre test to Post Test

- First Sketch: $r = 0.20$, $p=n.s.$
- Last Sketch: $r = 0.46$, $p=0.02$
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
Pre Test

- Control
- Progressive Alignment

![Diagram showing proportion of incorrect answers for Not Answered, Guessing, and Surface Penetrative Incorrect during the Pre Test.]

Post Test

- Control
- Progressive Alignment

![Diagram showing proportion of incorrect answers for Not Answered, Guessing, and Surface Penetrative Incorrect during the Post Test.]

**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

Control
What drove this effect?