Separating the representation from the science: Training students in comprehending 3D diagrams

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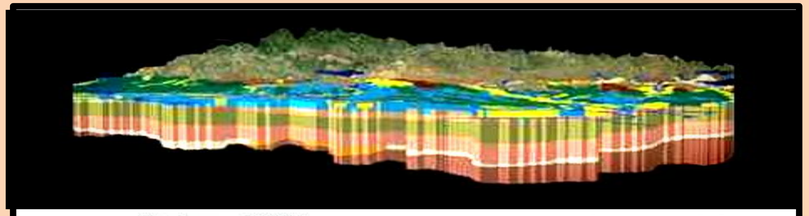
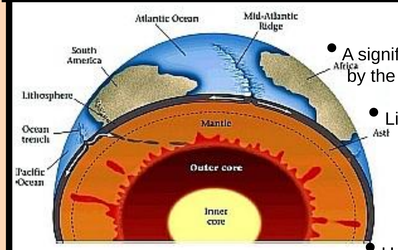




1. The Problem

- A significant number of geology students are confused by the 3D diagrams used to explain geology concepts (Kali and Orion, 1996)
- Little research has examined what makes the 3D diagrams hard to understand

2. Objectives

- Determine what visual properties cause the comprehension problem
- Use this knowledge to effectively train students in visualization literacy

3. Methodology

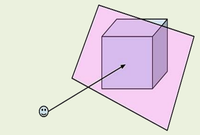
- 11 participants recruited from Rutgers University
- Participants asked to draw specific cross-sections of various 3D diagrams representing typical geologic structures
- Data collected by videotaping participants' problem solving process
- The participants words, gestures and drawings were analyzed (verbal protocols) using a grounded theory approach (Glaser, 2003)

Verbal Protocols are also called "thinking aloud." During the videotaping sessions, we tried to prompt the participant to vocalize their thoughts in such a way so as not to interrupt their thinking processes.

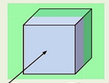
Grounded Theory is a method for analyzing data that assumes that every researcher carries personal biases in data interpretation. It requires that the researcher look for

- more than one instance of an observed behavior
- any examples of contrary behavior

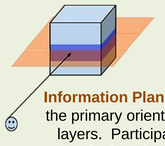
Our study focused on finding such examples.



Viewing Plane describes the orientation assumed by viewers. Participants often remarked on their viewpoint at the beginning of a problem: "So this, again I'm looking from this angle.?" (P3)



Cutting Plane gives the orientation of the cross-section. The cutting planes in our problems were at various angles from the vertical.



Information Plane describes the primary orientation of the layers. Participants often remarked on the difficulty of curved layers.

4. Summary of Analysis

- Participants solved 11 / 15 problems on average
- Number of solved problems ranged from 6 to 15
- Cutting planes and information planes that deviated from being parallel or perpendicular to a participants' expected coordinate system caused significant problems
- Problems with deviations for both cutting and information planes were significantly harder than deviations for only one plane

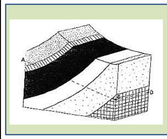
A more extended analysis has been published elsewhere (Oh, 2011).

5. Example From the Verbal Protocol Results

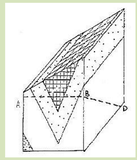
Angled cross-sections (cutting planes) cause confusion

So do curved layers

- **Data from gestures**
  - **Participants rotated paper to make layers horizontal and/or cutting plane perpendicular to the horizontal (horizontal being defined by the observer's viewing plane)**
  - **Participants sometimes sketched horizontal cutting planes or gestured same**
- **Data from spoken words**
  - **Participants noted that the angle of the cutting plane was where they encountered difficulties**
  - **Participants also remarked on the difficulty of visualizing curved layers**

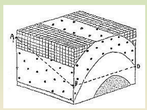


"I think I have troubles with the angle, that's the problem for me, I guess…"(P8)



"This one is harder, maybe because the angle goes the other way." (P8)

"If this slice is vertical verti.. totally horizontal, I would have five layers. But now this is going down [Pointing to the cut], uh.. the slice is being taken at an angle." (P6)



"It's not consistent in every side, so… trying to picture the layer I have to cut… this is hard… I don't know." (P1)

"The problem there is an angle that goes across a couple of diffe rent patterns, and then there is another curve over here, that creates more angles, which makes for me much harder."(P8)

"This one was more difficult because didn't have straight lines an ymore, the curve is coming from inside the slices." (P7)

"This is different because it's curved right there… I'm just drawing the bottom part.. but I'm not sure that's gonna be incorporated into the, the final pattern." (P9)

"The next layer is going to be a little more complicated because it has a curve that I will need to take into consideration as well." (P7)

6. Discussion

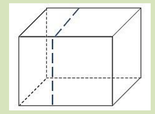
- The comprehension problems arise in part because these deviations forced participants to mentally re-orient their viewing perspective and thus, increased their cognitive load.
- **Re-orienting perspective – changing viewpoint – was so difficult that the participants' response was to change the cutting plane orientation.**

7. Implications for a Training Program

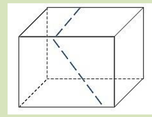
- Students need to learn that a problem is the solved similarly regardless of the orientation of the cutting plane or information plane relative to the viewing plane
- Difficulties reflect orientation issues more than geologic content issues.
- Our studies also suggest that moving from the simple already understood orientation to the more difficult orientation in small steps will give students the desired strategies for comprehending 3D visualizations.

8. Future Work: Test Proposed Training Plan

- Increase cutting plane angle to vertical from 0 to 45 in small (5-10) steps
- Increase curvature of layers slowly from flat to chevron

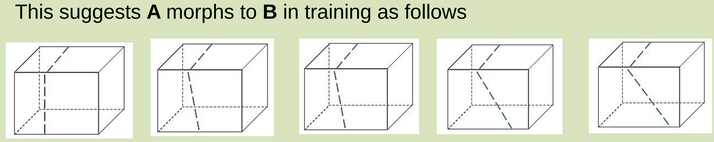


A. Easier



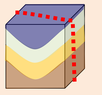
B. Harder

This suggests **A** morphs to **B** in training as follows



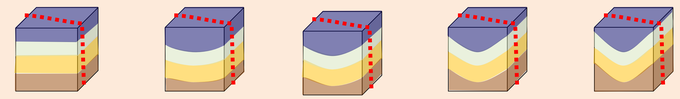
A **A1** **A2** **A3** **A4 (B)**

A. Easier



B. Harder

This suggests **A** morphs to **B** in training as follows



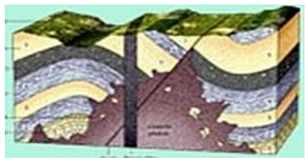
A **A1** **A2** **A3** **A4 (B)**

9. References

Y. Kali and N. Orion, "Spatial abilities of high-school students in the perception of geologic structures," *Journal of Research in Science Teaching, vol 33*, no 4, pp 369-391, 1996.

Glaser, B. G. *Doing Grounded Theory – Issues and Discussions*. Sociology Press, 2003

Oh, K., Halpern, D., Chiang, J., Tremaine, M., Bemis, K., and Silver, D., Which properties in 3D visualizations cause comprehension difficulties? *ASIS&T Proceedings*, 2011.



10. Acknowledgement

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