Improving Geoscience Students' Spatial Thinking Skills: Applying Cognitive Science Research in the Classroom

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The Problem(s)

Spatial thinking skills are critical to success in many subdisciplines of the geosciences (and beyond). Undergraduate students in introductory and upper-level geoscience courses bring a wide variety of spatial skill levels to the classroom:

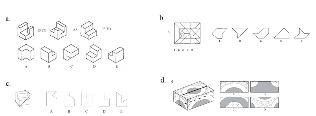


Figure 1. Example questions from the spatial skills tests used in this study. a. The Purdue Visualization of Rotations Test. Subjects are asked to identify what the object at the top right would look like if rotated in the same fashion as the first object. b. The ETS hidden figures test. Subjects are asked to identify which of the five shapes, A-E, can be found in the figure on the left. c. The ETS planes of reference test. Subjects are asked to identify the correct shape of the intersection of the plane and the object. d. Our block diagram test. Subjects are asked to identify the correct cross-section.

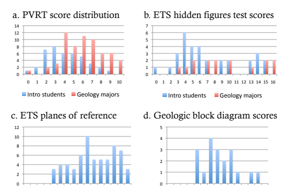
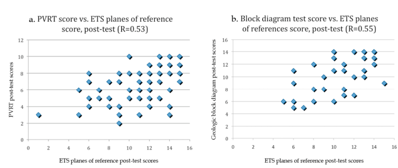


Figure 2. Distributions of pre-test scores for Carleton College geology students in Physical Geology (a & b only) and upper-level Geology courses (a-d). The x-axis shows the number of questions answered correctly, and the y-axis shows the numbers of students getting that score. a. PVRT. b. ETS hidden figures. c. ETS planes of reference. d. Our block diagram test.

It is not unusual for individual students to excel in some of these areas while struggling in others:

Figure 3. a. Graph of post-test scores on the Purdue Visualization of Rotations Test vs. ETS planes of reference test for all students in our study who took both tests (N=89). Although R=0.53, indicating a statistically significant correlation of these two skills, note that some students who excel at one of these skills are very weak in the other. b. Graph of post-test scores on the block diagram test vs. the ETS planes of reference test for all students in our study who took both tests (N=32). With R=0.55, these skills are also moderately strongly correlated, with similar scatter.



Although pre- and post-test comparisons show that student skill levels typically improve over the course of an academic term, average gains are quite modest:

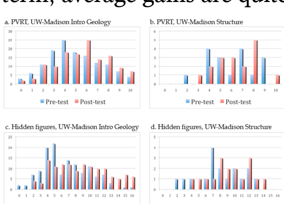


Figure 4. Examples of the distributions of student scores on the spatial skills tests used in this study. The x-axis shows the number of questions answered correctly, and the y-axis shows the numbers of students getting that score. The left to right shift in distributions of scores from pre-test to post-test indicates the average improvement in that particular spatial thinking skill, for that set of students. The extremely wide range of spatial skill levels in each class creates a large overlap of pre- and post-test scores. These distributions are typical for the classes in our study. a. Purdue Visualization of Rotations Test (PVRT), UW-Madison spring 2010 introductory geology class. b.PVRT, UW-Madison spring 2010 structural geology class. c. Educational Testing Service (ETS) hidden figures test, UW-Madison spring 2010 introductory geology class. d. ETS hidden figures test, UW-Madison spring 2010 structural geology class.

Research-based Strategies

Cognitive science research suggests strong strategies for building students' spatial skills. Progressive alignment and gesturing can be used to scaffold understanding. Practice is essential, and time on task is correlated to improvement.

Progressive Alignment

Progressive alignment is the process of moving from the comparison of very similar to less similar objects. Visualizing a slice through the interior of an object requires imagining how it differs from the exterior. If the interior structure varies gradually and regularly, we expect that progressive alignment will help students move from visualizing near-surface slices through an object to visualizing slices farther away from the visible surfaces. We are preparing to test this hypothesis.

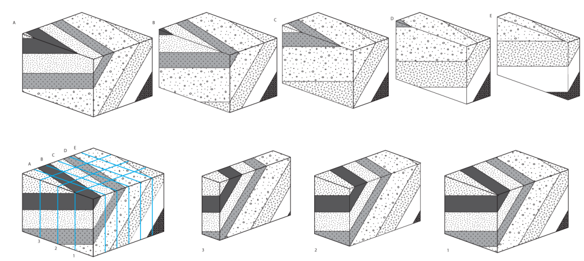


Figure 5. Block diagram of dipping beds and serial cross-sections through the block in two directions. Subjects are given half of the geologic block diagram test as a pre-test, shown a series of blocks like these (of these dipping beds, an upright anticline, plunging folds, and faulted horizontal strata; see figure 6), and then given the block diagram test as a post-test. The control group will be shown the same four blocks, without the slices, and told to think about slices through the interior for the same amount of time as the experimental group studies the sliced blocks.

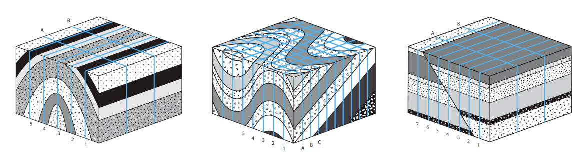


Figure 6. The other three block diagrams used in this experiment: an upright anticline, a pair of plunging folds, and horizontal strata cut by a reverse fault.

Gesturing

Gesturing has proven effective in moving younger students from incorrect problem-solving strategies to correct strategies in other disciplines. We are currently testing whether it can do the same in geoscience. Subjects are asked to gesture (a) how they would make a playdoh model of a block diagram (without any actual playdoh), (b) where they would slice it to see an indicated cross-section, and (c) in what direction they would look at the block model to see the slice.

Figure 7. Gesture helps geoscientists decipher and communicate about geological geometry and processes. Cognitive science research suggests that explicitly teaching students to gesture may facilitate the development of their spatial thinking skills.

While we do not yet have enough data to draw any conclusions from these experiments, initial results suggest that this may be an effective strategy for developing geoscience students' penetrative thinking skills.

Acknowledgements

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