Improving Spatial Visualization Skills in the Undergraduate Geoscience Classroom through Interventions Based on Cognitive Science Research

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Context

3-D spatial visualization is an essential prerequisite for understanding geological features at all scales. Undergraduate geoscience students, including majors, bring a wide range of spatial visualization skill levels to the classroom:

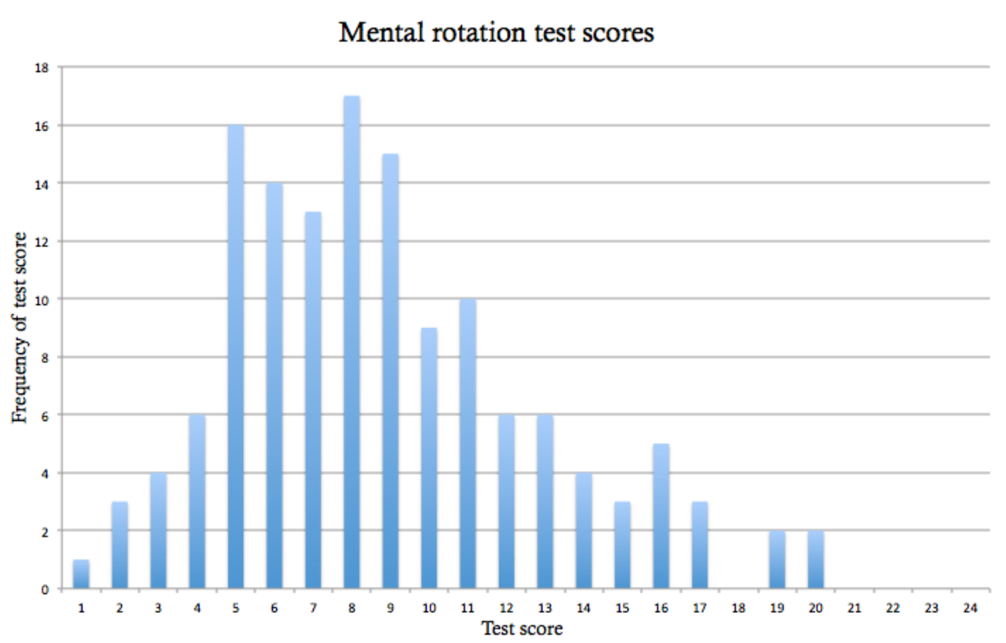


Figure 1. Examples of distributions of Vandenberg & Kuse Mental Rotation Test scores for students in Mineralogy, Structural Geology, and Sedimentology/Stratigraphy courses.

Individuals excel at some spatial tasks while struggling with others:

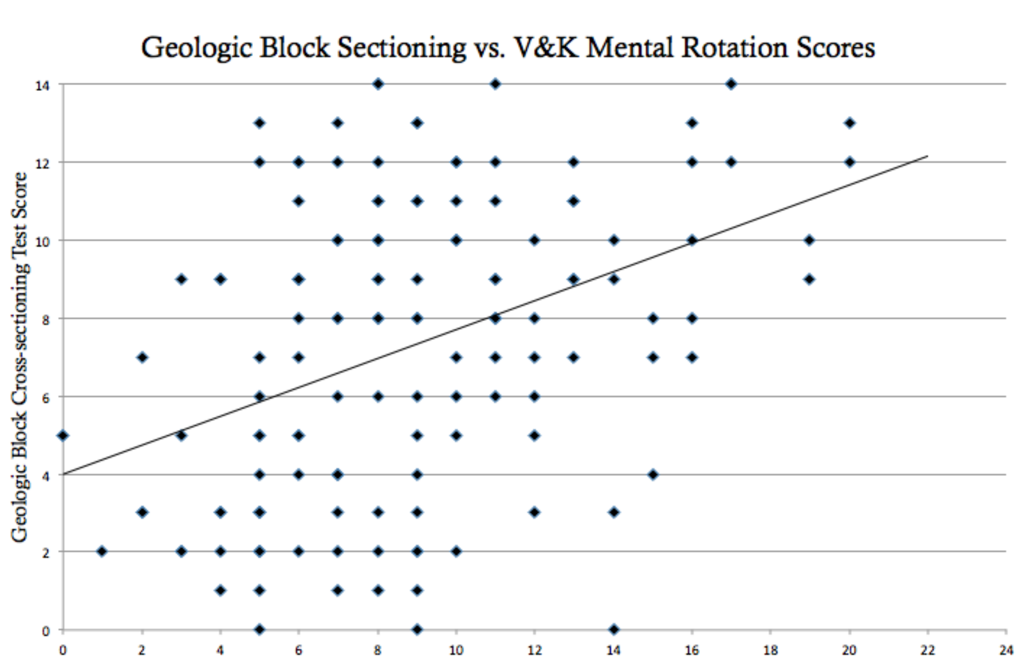


Figure 2. Scores on the Geologic Block Cross-sectioning Test vs. the Vandenberg & Kuse Mental Rotation Test (N=142). Although R=0.40, indicating a statistically significant correlation of these two skills, some students who excel at visualizing a cross-section through a geologic block diagram have weak mental rotation skills.

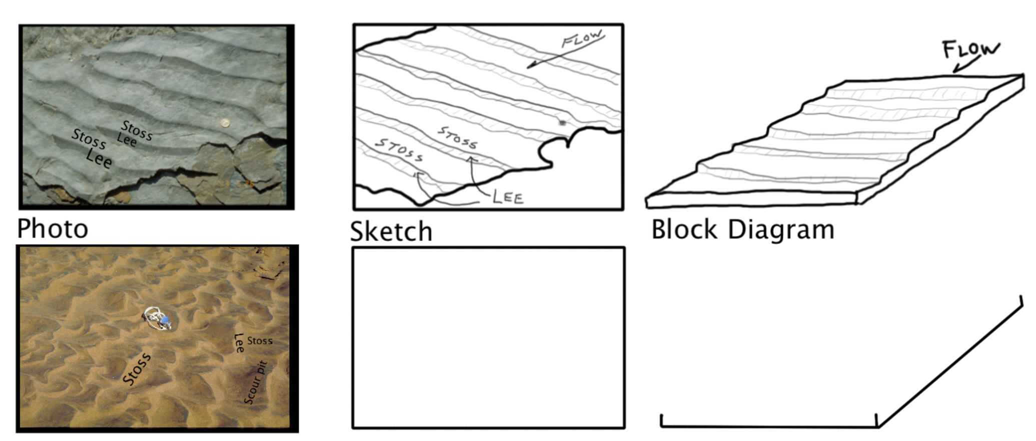
As a group of geoscientists and cognitive psychologists, we are collaborating to apply the results of cognitive science research to the development of teaching materials to improve undergraduate geology majors' spatial visualization skills.

Applying Strategies from Cognitive Science Research to Geoscience Tasks

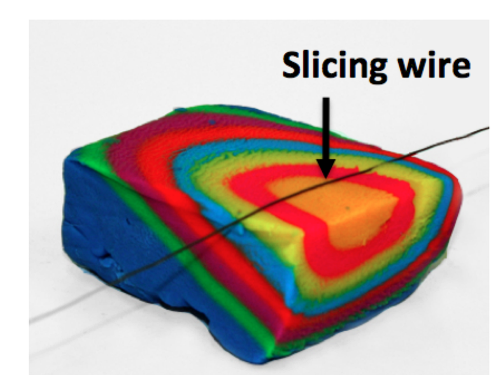
3D Sketching and Prediction

Sorby (2009) showed that sketching in 3D improves spatial visualization skills and results in higher rates of success in undergraduate engineering courses. Similarly, making predictive sketches about the interior of an object, and immediately seeing the correct answer, boosts performance on penetrative thinking tests (Gagnier et al., 2013).

As experts, we often look at a 2D exposure of a geologic feature and imagine its 3D form. Making 3D sketches may help students to make the same connections. In addition to giving students opportunities to practice sketching, we have video tutorials showing them how we sketch in 3D.



For some students, visualizing the interior of a geologic block (representing a 3D geologic structure) is a significant challenge. In this exercise, students sketch what they think a play-doh model of a geologic structure will look like after being cut by the wire. They then see the sliced block and compare it to their prediction.



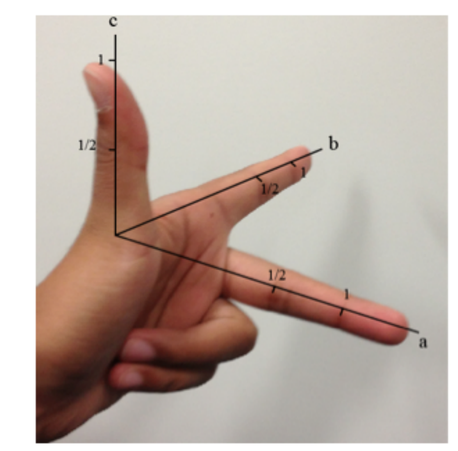
Analogy

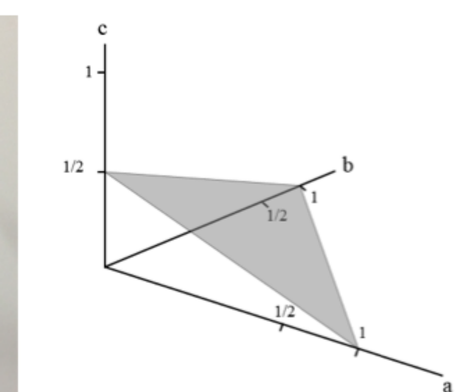
Analogies can help us to use what we know about familiar objects to make predictions about and develop our understanding of less familiar objects (Gentner, 1983).

Fruit salad shares some key characteristics with a bowl of rocks, and a conglomerate is similar to a bowl of rocks and sand. Thinking about these similarities may help students to visualize the interiors of rock units.

Gesture

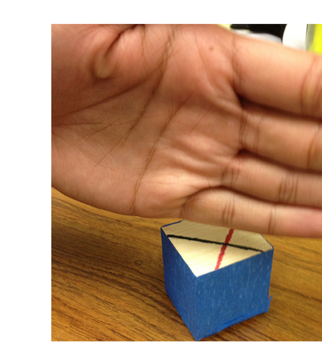
Students who gesture about spatial relationships perform better on spatial visualization tests than students who don't gesture, perhaps because gesture provides a mechanism for cognitive offloading (Goldin-Meadow et al., 2001).





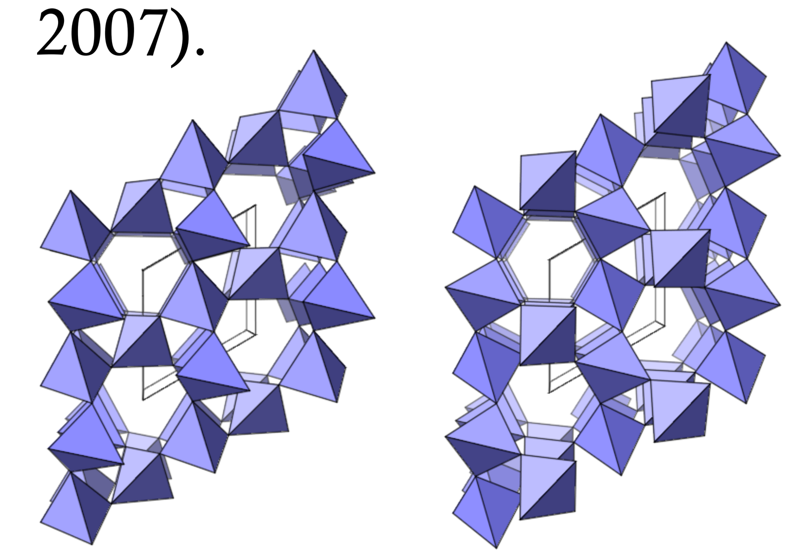
In Mineralogy, many students struggle to understand Miller Indices. In this exercise, students use one hand to gesture crystallographic axes and the other hand to gesture the orientations of various crystallographic planes. Working in teams, students check each other's gestures for accuracy.

Many students assume that surficial features go "straight in," at the hand sample and outcrop scales. In this exercise, students gesture their predictions of how surficial features will go into wooden blocks. They then unwrap the blocks to test their predictions.



Progressive Alignment

Making visual comparisons of similar objects or structures helps learners to identify key differences. Progressing from comparisons of very similar objects to less similar objects scaffolds the ability to identify salient features (Gentner et al., 2007).



Mineralogy students may not recognize key features of 3D crystallographic structures from 2D representations of those structures. We have students compare pairs of minerals, starting with extremely similar pairs and moving to more dissimilar pairs, to identify those important characteristics.

References

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