New Approaches to Spatial Thinking in the Context of Structural Geology

Laurel Goodwin, Geoscience, Department of Geoscience, University of Wisconsin-Madison; Carol J. Ormand, SERC, Carleton College; Kristin Gagnier, Psychology, Temple University; Kinnari Atti, Psychology, Temple University

Introduction

Spatial thinking skills are essential for student success in solving 3D problems. Yet even the brightest students may struggle with 3D visualization and manipulation. Recent research shows, however, that spatial thinking improves with practice, and can improve more rapidly with intentional training. 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 expand undergraduate structural geology students’ spatial thinking skills.

Research into the utility of incorporating these strategies into a Structural Geology course at UW-Madison began in Spring 2012. Preliminary results allow a comparison between the results of more traditional introductory teaching strategies and those that employ new concepts from cognitive science.

2012: Baseline Study

Prior to 2012, we introduced a number of approaches to giving Structural Geology students practice thinking in 3D. For example, we moved away from a more traditional one-day field trip format, where we integrated data collection and interpretation, to a 2-day exercise. We now make observations and measurements on Day 1 and interpret data on Day 2.

We also added short exercises designed to build practice of specific, relevant spatial thinking skills into each lab.

Figure 1. This exercise, added by TA Rachel Murphy in 2011, requires student to construct cross sections through an object with a known interior - the human foot - using only the concept of a geologic cross section by analogy.

The Geoscience Visualization Center provides the opportunity to explore surfaces picked from a 3D seismic volume collected across the Nankai accretionary prism. Among other features, students see slip-parallel corrugations on curvilinear thrust fault surfaces.

Figure 2. An image of an ocean trench, as seen in an internet-enabled Google Earth software.


Employing New Concepts from Cognitive Psychology Research

Gesture

Structural geologists naturally use gesture both as an adjunct to verbal description and as a tool in solving 3D problems. However, students who gesture about spatial relationships also 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).

Figure 3. Christy Barszewski and Dana Smith introduce students to an exercise in back projection for an Advanced Structural Geology lab.

Most students assume that planar structures extend into a rock volume perpendicular to the surface on which their traces are viewed. In this exercise, introduced in 2013, pairs of students were asked to gesture all possible orientations of each of two ‘fractures’ traced on a wooden block, after which the block was unwrapped, revealing true orientations.

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., 2004). In 2014, we used this approach to help students understand how varying displacement vectors and orientation of marker horizons can produce very different separation across faults.

Students were given a homework assignment that began with block diagrams to illustrate how map patterns are produced by faulting followed by erosion.

This explanation was followed by a series of block diagram + map pairs. Students were required to (1) indicate fault type, (2) record displacement vector and (3) describe strike separation. Example pairs show how identical displacement vectors produce different separation when marker horizons have different orientations. Changing displacement vectors provides a progression to less similar objects.

References

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Testing the Effectiveness of Interventions

Pre- and Post- Tests

Pre- and Post-tests show statistically significant gains in spatial thinking skills in four out of five categories tested in every year but one. In 2013, students showed no gains in ability to produce cross sections through block diagrams (purple arrow). There is no statistical difference between gains attained in 2012 and those obtained in 2014. The same teaching team was in place in 2013 and 2014. So what happened?

We speculate that two factors stymied advances in student development in this area: (1) We were kept out of the field by bad weather. Although we substituted an ‘armchair field trip’ for the real thing, using maps, rocks, and photographs, it clearly wasn’t the same. (2) The new exercises we introduced took more time than expected, and some material was jettisoned. We inadvertently left out our foot sectioning exercise, and had to abandon our visit to the visualization lab in order to cover key material. In 2014, we moved more of the cognitive science exercises into homework assignments, and made space for others more judiciously. The data shown below demonstrate the utility of both keeping the old and adding the new exercises.

Embedded Assessments

Although we do not see evidence that these new interventions increased spatial thinking skills beyond gains acquired through existing interventions, our preliminary analysis suggests they have increased our students’ 3D problem-solving ability. In particular, student performance on the embedded assessment shown below improved dramatically in 2014 (red asterisks, left). Lab grades (not yet analyzed) were unusually high, and final grades exhibit statistically significant improvement (blue asterisks).

Notes and References


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