Developing and Testing Materials to Improve Spatial Skills in Upper Division Geoscience Courses

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Context

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

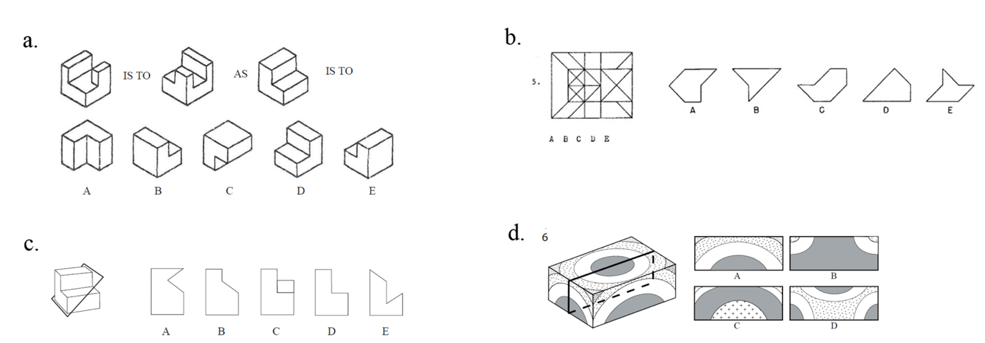


Figure 1. Example questions from the spatial skills tests used in this study. a. The Purdue Visualization of Rotations Test. Subjects are asked to identify what the object at the top right would look like if rotated in the same fashion as the first object. b. The ETS hidden figures test. Subjects are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

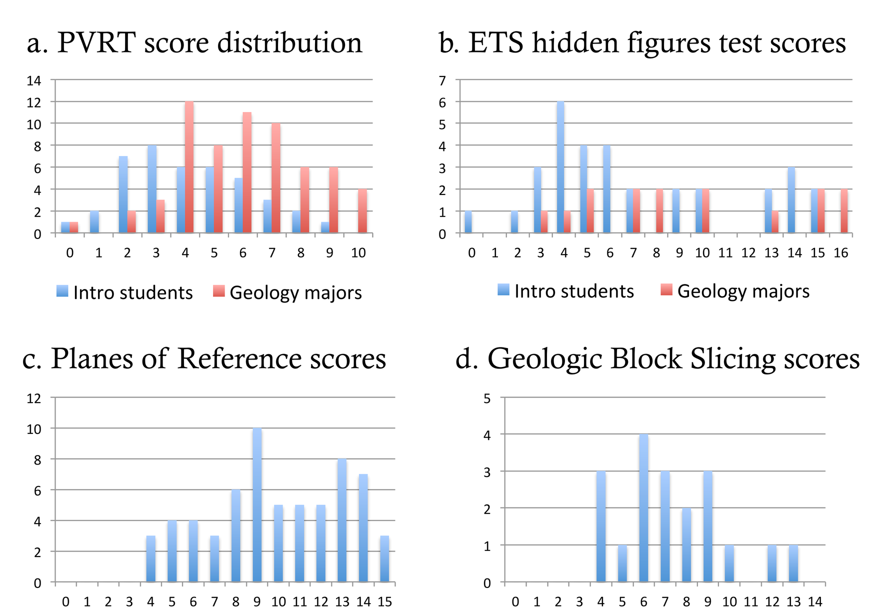
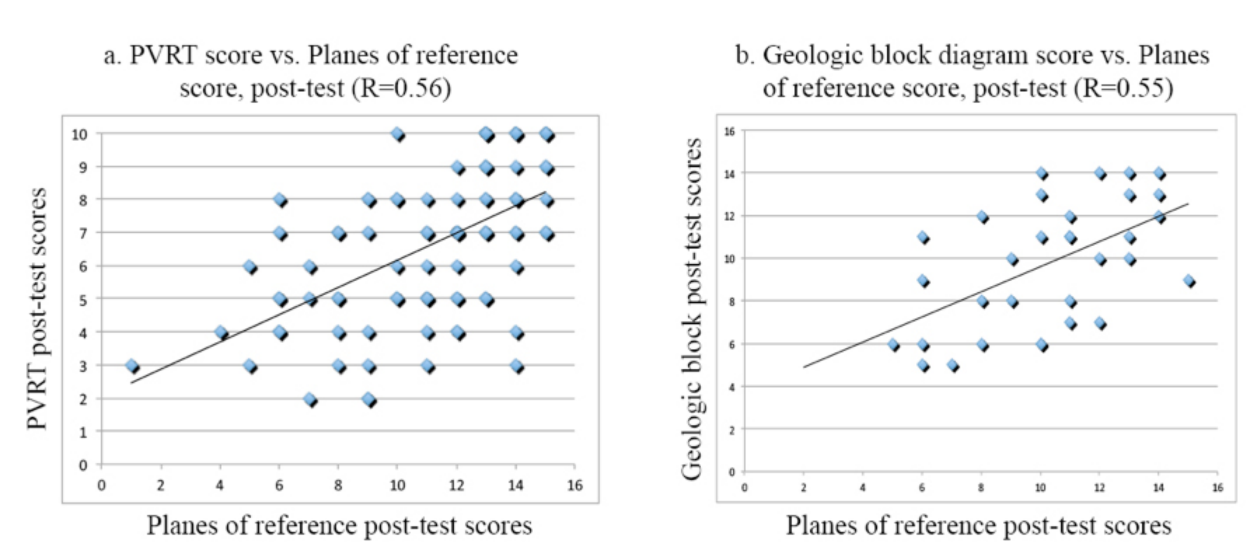


Figure 2. Distributions of pre-test scores for Carleton College geology students in Physical Geology (a & b only) and upper-level Geology courses (a-d). The x-axis shows the number of questions answered correctly, and the y-axis shows the numbers of students getting that score. a. PVRT. b. ETS hidden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

It is not unusual for individual students to excel at some spatial skills while struggling with others:

Figure 3. a. Graph of post-test scores on the Purdue Visualization of Rotations Test vs. Planes of Reference test for all students in our study who took both tests (N=89). Although R=0.56, 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 Geologic Block Slicing Test vs. the 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:

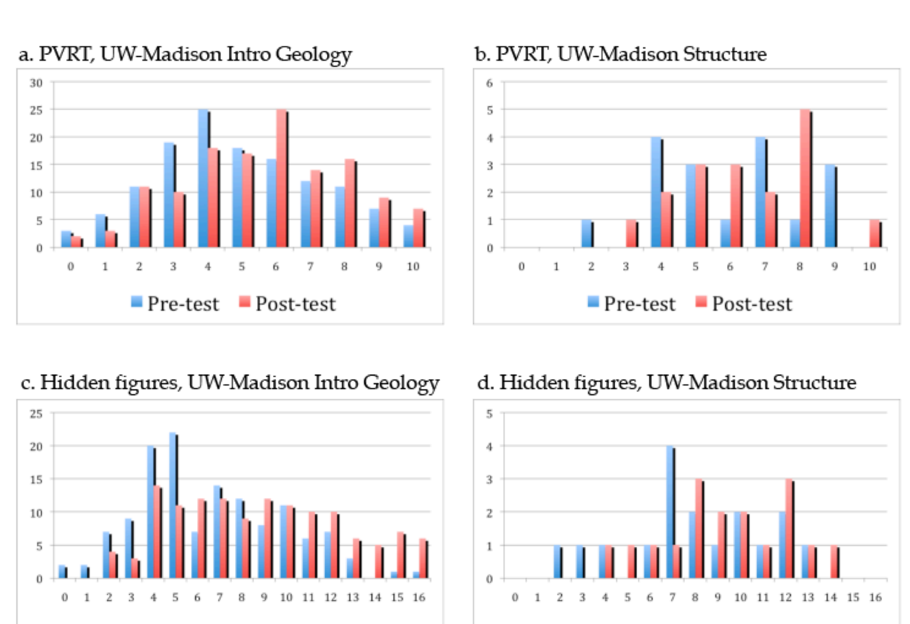


Figure 4. Examples of the distributions of student scores on the spatial skills tests used in this study. The x-axis shows the number of questions answered correctly, and the y-axis shows the numbers of students getting that score. The left to right shift in distributions of scores from pre-test to post-test indicates the overall 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.

Goals of the project

Students with strong spatial skills are more likely to persist in STEM fields. Penetrative thinking – imagining the interior of an object – is one of the key spatial skills in the geosciences. We are working to expand the pool of students who can succeed in geoscience by helping students with poor penetrative thinking skills overcome that barrier to success. If effective, this approach to improving students' spatial skills will provide a model for other disciplines.

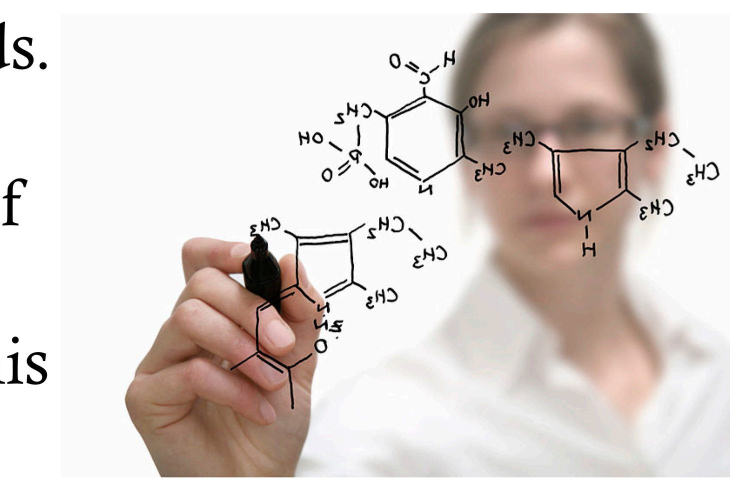


Image courtesy of the U.S. Department of Defense.

Methods: Research-Based Curricular Materials

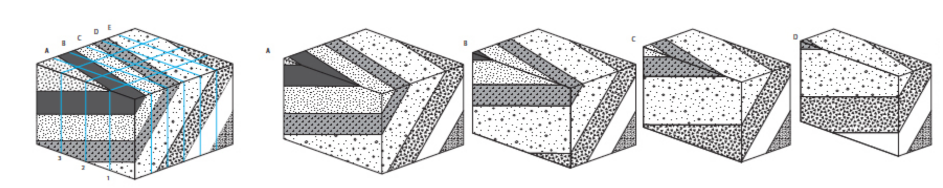


Figure 5. Block diagram of dipping beds and serial cross-sections through the block, parallel to one of the front faces. Exercises walk students through the process of constructing such cross-sections, starting with one that is very near one face.

Figure 6. 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.

Progressive alignment is the process of moving from the comparison of very similar to less similar objects, in order to identify salient differences. Visualizing a slice through the interior of an object requires imagining how it differs from the exterior. We are using progressive alignment to help students move from visualizing near-surface slices through an object to visualizing slices farther away from the visible surfaces, and to visualizing slices through increasingly complex structures. **Directed gesturing** has proven effective in moving K-12 students from incorrect to correct problem-solving strategies in other disciplines. We are testing its efficacy in undergraduate geoscience courses.

Project Timeline & Evaluation

	Summer 2011	2011-2012	Summer 2012	2012-2013	Summer 2013	2013-2014
Planning & Development	Planning meeting: develop new spatial thinking tests	Develop exercises for Mineralogy	Plan deployment of exercises	Develop exercises for Structure & Sed/Strat	Refine exercises	Final revisions to exercises
Data Collection & Evaluation		Collect baseline data	Analyze baseline data	Deploy and test exercises	Analyze classroom data	Deploy revised exercises; analyze data
Dissemination		Website: summary of prior research	Website: post exercises and supporting materials	Present preliminary results at meetings	Draft journal article	Journal article & website: exercises and results

Evaluation of the curricular materials is based on pre- and post-tests of spatial thinking skills administered in each of three classrooms, throughout the project. In year 1 (2011-2012), we collected baseline data on the improvement of spatial thinking skills over the course of the semester in each of our target classrooms, without intervention. In years 2 & 3 (2012-2014), we are collecting comparable data on the improvement of students' spatial thinking skills, using our curricular materials in the same courses. If we see statistically greater improvement, we will be able to quantify the effectiveness of the curricular materials. **Evaluation of this project,** conducted by our external evaluator, focuses on validating the research plan and the methods of evaluating our classroom data, and providing a summative evaluation at the conclusion of the project.

http://serc.carleton.edu/spatialworkbook/index.html

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