What is the Role of CyberGIS in Teaching Students to Think Spatially?

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My interest in this workshop arises from my research program, focusing on the development of spatial thinking skills in the undergraduate geoscience student population, and my work on faculty professional development, with an emphasis on bringing research-based practices into undergraduate STEM teaching.

For the past several years, I have collaborated with a team of cognitive scientists and geoscience faculty in a multi-faceted program of research focusing on characterizing, assessing, and developing the spatial thinking skills of students in undergraduate Geology courses. Spatial thinking is fundamental to the geosciences, for tasks as diverse as map-reading and navigation; understanding atmospheric and oceanic circulation patterns; visualizing groundwater flow, the Earth’s magnetic field, crystallography, and structural cross-sections; and interpreting seismic reflection profiles. Furthermore, spatial thinking is not a single skill. The tasks listed above require a variety of spatial skills, including understanding scaled representations; visualization of 3D objects, patterns and motions; penetrative thinking (imagining the interior of an object); and disembedding (seeing relevant data in a noisy pattern). Unfortunately, there is no formal teaching of spatial thinking skills in the K-12 curriculum. As a result, students arrive in undergraduate geoscience classrooms with a wide range of abilities in this area (e.g., Murphy et al., 2011). A number of studies, in geoscience education and in cognitive science, have shown that spatial skills do improve with practice (e.g. Titus and Horsman, 2009; Ormand et al. 2014). However, average gains over a single semester tend to be quite modest. It is therefore cogent to consider how we can facilitate the development of spatial thinking skills in our geoscience courses.

Students arrive in undergraduate geoscience classrooms – whether introductory general education courses or upper-level courses for majors – with a wide range of spatial skills. For example, on instruments measuring skills including mental rotation, penetrative thinking, and disembedding, some students demonstrate proficiency on every measure, while others clearly struggle with every task. Moreover, some students are proficient at some kinds of spatial tasks but not at others (Figure 1). To the extent that these skills are necessary to understand geoscience concepts and solve geoscience problems, weak skills can be a significant barrier to student learning.

Figure 1. Student test scores on the Purdue Visualization of Rotations Test (a test of mental rotation) vs. their scores on the ETS planes of reference test (a test of penetrative thinking). While the skills are strongly correlated, many students excel at one but not the other.
Cognitive science and STEM education research suggest many kinds of “interventions” that may be effective in improving students’ spatial skills. Several are tried and true geoscience teaching methodologies, like taking students into the field or using 3D physical models in laboratory exercises. Others, however, are less familiar. In several studies, Susan Goldin-Meadow and colleagues have found that students who are required to gesture are more likely to use correct problem-solving strategies than those who are prevented from gesturing (e.g. Broaders et al., 2007). It seems intuitively obvious to many geoscience educators I’ve talked to that students who have strong mental models of 3D objects gesture when they describe those objects; what also appears to be true is that having students gesture about spatial relations may help them to build mental models. This is, of course, just one example. Our team has developed a set of two dozen teaching activities, using principles derived from cognitive science research, designed to strengthen the spatial thinking skills of students in upper-level Geology courses. These can be found on our project website: http://serc.carleton.edu/spatialworkbook/index.html.

I am excited about the opportunity to think collaboratively about the potential for using CyberGIS as a platform for developing undergraduate students’ spatial thinking skills, and to work with other attendees to develop a roadmap leading to curriculum guidelines and recommendations for adoption in a broad range of courses. In particular, I think that CyberGIS has the potential to help “spatialize the curriculum” a recommendation arising from a National Research Council 2006 report.

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References:


