# Practical Lessons from Research on Field Cognition and Behavior

**Research data can provide insight into ways training can be improved, including providing novice students with explicit instructions for how to spend their time in a field and for transferring knowledge onto a map.**

How does expertise influence thinking and working in geologic field environments? We studied this question during "Learning Across the Expert-Novice Continuum: Cognition in the Geosciences," a collaborative research project funded by NSF's REESE program. The project brought 67 geologists—from sophomore undergraduate majors through geologists with decades of field experience—to a field site in the Rocky Mountains (FIGURE 1). The data we collected provide useful insights into the role that knowledge, general intelligence, spatial visualization skills, prior experience, navigation, and even emotion play in mapping performance (Hambrick et al., in press).

Students prepare to explore the "Whaleback Anticline" to understand the structures exposed in an abandoned strip mine in eastern Pennsylvania. (Photo by David Steer)

## PURPOSE

Little research has considered the nature of expert field behavior, although most geologists would agree that fieldwork is an "essential" component of geologic training (Macdonald et al., 2005). Many field educators also have instincts about the most effective way to teach field mapping. We set out to study the nature of geoscience expertise in the field, to compare expert cognition and behavior with that of novices, and to generate new insight into best practice for field instruction. This work followed on the heels of seminal works in cognitive psychology that have considered the role of expertise in problem solving (e.g., Chase and Simon, 1973).

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## THE STUDY

Participants were chosen from a larger volunteer pool (over 200 applicants in two years) to represent a range of expertise levels and allow consideration of the roles of gender and age on cognitive performance. In all, seven cohorts of geologists participated over two field seasons.

Upon arrival at a central field site, participants took a battery of paper-and-pencil tests and a set of computer-based tests. This evaluated basic knowledge about geoscience, general intelligence, spatial working memory capacity, and geologic working memory capacity. The next day, participants took timed paper-and-pencil tests that evaluated spatial visualization ability and working memory capacity.

A two-hour guided introduction to local stratigraphy was followed by the mapping task, in which participants were released, one-by-one, into the field area with the task of creating a bedrock geology map. Each carried a topographic map and aerial photo of the field area, as well as a hand lens, rock hammer, acid bottle, and colored pencils. GPS units recorded their movement from the moment of release into the field until handing in a map at the end of the day. Participants took between three and seven hours to complete their field mapping; each was interviewed that evening about the day's mapping, their mapping experiences, and how they were taught to map.

## OVERARCHING FINDINGS

Using GIS technology, we digitized and analyzed maps generated by study participants (FIGURE 2). Comparing their maps with a consensus bedrock map provided us with a quantitative measure of mapping accuracy and structural interpretation. These data were compared to cognitive test results, GPS data of navigation patterns during mapping, think-alouds recorded by a subset of participants during their mapping, and post-mapping interview data. A few key findings were surprising and may have significant implications for field instruction.

### Cognitive Influences on Map Accuracy

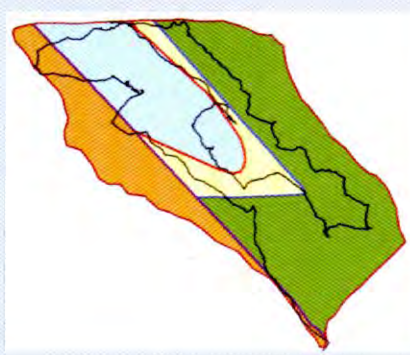
Spatial visualization has long been assumed to be higher among geologists than among other adults. Certainly, geologists have a higher spatial visualization ability than the general public, although the same can be said of adults in visual fields, including architecture, art, and chemistry (e.g., Salthouse et al., 1990). In this study, we found that both geological knowledge, as measured by a 19-item version of the Geoscience Concept Inventory (GCI), and spatial visualization ability correlated positively with accuracy in the field mapping task ($r = .60$, $p<0.001$ and $r=.28$, $p=.02$, respectively).

More important, however, we found a statistically significant interaction between geological knowledge and spatial visualization ability: The latter factor positively predicted map accuracy in novices but not in experts. This suggests that acquisition of domain-specific knowledge in geology replaces the need to exercise spatial visualization skills in field mapping. In other words, spatial visualization ability may be important as a predictor of the ability to field map initially, but may lose its predictive power as conceptual understanding of geological concepts is acquired. We found no relationship between map accuracy and demographic variables, namely, age and gender.

### Navigation Behavior

The GPS data were considered holistically. Did experts and novices display different characteristics in how they moved through the map area? In interviews, many indicated that their navigation strategy was driven by what they had been taught, i.e., to move to high points, zigzag across the study area, find and walk out contacts, walk across or along strike, or walk along dip. Overall strategies were influenced by "on the fly" decisions related to the geology (e.g., wanting to find outcrop), field conditions (e.g., avoiding areas of dense vegetation), and personal comfort (e.g., exhaustion). None of these strategies, however, was shown to be significantly better than another.

GPS data were also used to generate scores on a suite of variables, such as number of times a track was crossed, distance walked, and elevation. In general, track variables correlated to two larger constructs: thoroughness (how much of the area was covered) and speed (how quickly the area was covered). Of importance to instruction were the observed differences between expert and novice navigation. Those participants with significant previous mapping experience showed a significant correlation between GCI scores and the thoroughness with which they covered the map area. Experts demonstrated a relationship between speed and correctness of structural interpretation, with faster mappers demonstrating better understanding of the underlying geologic structure. Fast novice mappers, on the other hand, were significantly less thorough, which was related to lower quality maps. All participants demonstrated a relationship between map quality and number of times that geologic contacts were crossed. Successful mappers,



**FIGURES 1 and 2: (Left) A view near the field area; (Right) Sample digitized map and GPS track. The different colors represent the four major rock units in the map area, and the solid black line is the participant's GPS track. The map has been distorted to obscure the study area, as per agreement with the site's owners.**

regardless of expertise or strategy, found contacts and crossed them repeatedly throughout the mapping day.

### Think-Alouds and Interviews

Audio data recorded by participants while mapping and post-mapping interviews provided insight into the background, reasoning, and emotions of our participants. Similar to the findings of Petcovic et al. (2009), expert mappers in this study considered three questions during the mapping process: Where Am I?; What Am I Looking At?; and What Does This Mean? Although both novice and expert mappers synthesized their field observations and made geologic interpretations, the nature of these interpretations varied. Novices appeared more concerned with determining the identity and distribution of rock types (especially in areas of poor exposure) whereas experts focused on developing a coherent model of the overall geologic structure. Novice mappers often failed to view the map as a model of the natural world and instead saw the map as an end-product in and of itself.

During interviews, we noticed an interesting disconnect between the information displayed on novice maps and their discourse about their maps. With few exceptions, participants were able to describe and explain a prominent geologic structure in the area. However, a large number of novices neglected to, or were unable to, place strike-and-dip symbols or indicate a structure on their maps. Consequently, their maps were often under-representations of their actual understanding. The most successful mappers formed a mental model of the underlying geologic structure either immediately upon viewing the aerial photograph of the map area or very early in the mapping task. They spent the rest of the task collecting field observations to confirm their initial model and/or to generate, evaluate, and discard alternate explanations. The least successful mappers rarely generated explanations or models of the underlying geologic structure in the field.

Our probing about participants' prior mapping experiences revealed that undergraduate programs require many different types of field experiences, from programs that require minimal fieldwork offered in a short two-week course to programs that require field experiences in nearly every undergraduate course. Undergraduate and graduate field courses also ranged from teacher-led tours of a region to inquiry-based autonomous mapping. In general, the most confident and excited novice mappers were those who had been given some prior autonomy in their mapping experiences.

## IMPLICATIONS FOR INSTRUCTION

These data cannot tell us how to build a better field training experience for budding geologists. They do provide insight into ways in which field camp and similar field-based instruction can be improved.

Novice mappers displayed a disconnect between the features included on their maps and the generally more-detailed understanding of structures within the field area elicited during interviews. This suggests they may need explicit and repeated instruction about best practice for transferring knowledge onto a map. Alternately, assessment of students' understanding of the geology of a map area should rely not only on the map produced, but also on an accompanying narrative.

The lack of a relationship between how participants moved through the entire field area and map accuracy suggests that no single strategy is the "best" approach. Many participants indicated, however, that they had been taught the "right" way to map. We suggest that students be taught multiple strategies.

A relationship did exist between map accuracy and the thoroughness with which participants covered the field area: The more of the field area novices saw, the more likely they were to generate a more accurate map. This, coupled with the difficulty novices had placing information on their maps, suggests that students may need explicit instruction on how to spend their time within a field area. This includes recognizing that a map is a model, rather than a final product, and that mapping should include generating and testing of the model itself.

Finally, the correlation between GCI scores, spatial visualization ability, and map accuracy bears further consideration. First, the GCI was developed as a measure of fundamental conceptual understanding of geoscience and was intended as a pre/post measure for entry-level geoscience courses. We suggest that a deep understanding of fundamentals is suggestive of deep understanding of more complex ideas, such as those needed to generate a bedrock map. The GCI could be used, then, as a predictor of student mapping ability, pointing towards those who might need more focused instruction. Furthermore, although spatial visualization ability is important for novice geologists, our results suggest that acquisition of a deep, conceptual understanding in geology may ultimately replace the need to use this ability in field mapping.

## ACKNOWLEDGMENTS

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# NAGT NEWS / Geo2YC Becomes First NAGT Division

Geo2YC, a group of NAGT members interested in two-year college (2YC) education, became the first special interest division of the Association on July 23. Creation of the Division was a recommendation of a June 2010 NAGT/NSF-sponsored workshop "The Role of Two-Year Colleges in Geoscience Education and in Broadening Participation in the Geosciences: A Planning Workshop." Workshop participants, and other interested 2YC geoscience faculty, petitioned the NAGT Executive Committee last April to create the new Division. A recent change in the NAGT Bylaws allows members to petition the Executive Committee to create a special interest division.

The mission of the new division is to:

- serve as a forum for exchanging information about 2YC geoscience programs
- create a professional network for geoscience educators at two-year colleges and other institutions with shared interests
- sponsor NAGT 2YC activities and make recommendations to the NAGT Council
- support and coordinate research on 2YC geoscience education
- advocate for 2YC geoscience education within NAGT and with other organizations

"Geo2YC will work closely with NAGT Sections, the Geological Society of America (GSA), and the American Geophysical Union (AGU) to expand opportunities for networking, professional and curriculum development, and geoscience educational research

NAGT
Geo2YC Division

at two-year colleges," said Bob Blodgett, chair of the Geo2YC organizational committee. The new division is electing its first officers in October, and sponsoring 2YC social functions at the GSA Annual Meeting in Minneapolis and December AGU meeting in San Francisco.

The Division welcomes membership by four-year college/university faculty who share common interests with 2YC geoscience programs, students and geoscientists interested in teaching at a 2YC, and adjunct faculty teaching at all levels.

For more information on these events and about the Geo2YC Division see http://nagt.org/nagt/organization/nagt-2yc.html.