Field Guides

Get ready, get set, go…on a field trip

David W. Mogk

Field Guides 2011;24;477-482
doi: 10.1130/2011.0024(23)

Notes

The Geological Society of America
Field Guide 24
2011

Get ready, get set, go…on a field trip

David W. Mogk
Department of Earth Sciences, Montana State University, P.O. Box 173480, Bozeman, Montana 59717-3480, USA

INTRODUCTION

Field instruction has been at the heart of the geoscience curriculum for over a century and a half. The field environment provides learners the opportunity to encounter nature in all its diversity, to experience firsthand the methods and strategies that geologists use to interrogate Earth, and to engage in the social interactions that animate geology as a discipline. The field environment provides a great opportunity for learners to learn science by doing science and to undertake fieldwork as developing scientists. This holds true for learners of all kinds, for K–12 and undergraduate students, continuing professional training for graduate students and working geologists, and informal learning by the general public. The purpose of this contribution is to provide an introduction to the many factors that could be considered in the design and implementation of a field trip to provide students with an optimal learning experience. You will have your own motivations and learning goals for your students based on their grade level, curricular needs, and geologic setting; the following ideas are presented as an overview to help you reflect on ways you can prepare to conduct a comprehensive and effective learning experience for your students in the field. A more complete coverage of these topics can be found in Butler (2008), Maskall and Stokes (2008), the special issue of the Journal of Geoscience Education on Teaching in the Field (Manduca and Carpenter, eds., 2006), many articles in Whitmeyer et al. (2009), and in a chapter by D.W. Mogk and C. Goodwin for a GSA Special Paper in preparation.

BACKGROUND

To start, it's useful to reflect on the special attributes of the field setting that impact learning by students. As master geoscientists and educators, we may lose sight of factors that are either novel to students or that may present barriers to learning:

- The physical scale of study in the field setting is typically large with respect to the observer. So, the perspective of the observer is internal to the object of study (the expansive natural setting) rather than an externalized viewpoint looking at small objects, e.g., in a laboratory setting (Bryant et al., 1992).
- Field studies employ the historical and interpretive traditions of geology which rely on the methodical observation of nature (Frodeman, 1995). Natural systems are open, heterogeneous, dynamic, complex and often ambiguous. It is a challenge for novice learners to engage this natural complexity, to know what is important, what to look for, and what to do in this type of setting. In a school laboratory, most objects on the lab table are relevant to the inquiry at hand, whereas for field based inquiry most objects in view are not relevant, and it is not immediately obvious to the novice what features are important (Goodwin, 1994; Reynolds et al., 2006).
- The affective domain has a large impact on learning in the field. The affective domain includes factors such as student motivation, attitudes, emotions, perceptions, and values (Krathwohl et al., 1973). The field setting can be a strong motivator to learn, inspiring a sense of awe, wonder and curiosity, and can help develop students' self-confidence in their ability to learn. Immersion in a natural setting engages all of the senses. Strong sensory inputs impact the affective domain and are coupled with cognitive and memory functions (Storbeck and Clore, 2007; Pessoa, 2008). However, fear and uncertainty about what to expect and do in a field setting can produce significant barriers to learning.
- Physical movement through a field environment produces unique perspectives that cannot be reproduced in a laboratory or virtually on a computer. Physical interactions of the human body with the surrounding environment have

Mogk, D.W., 2011, Get ready, get set, go…on a field trip, *in* Miller, J.D., Hudak, G.J., Wittkop, C., and McLaughlin, P.I., eds., Archean to Anthropocene: Field Guides to the Geology of the Mid-Continent of North America: Geological Society of America Field Guide 24, p. 477–482, doi:10.1130/2011.0024(23). For permission to copy, contact editing@geosociety.org.

important connections to human cognition. The brain uses the body's interactions with the world around us to build models that can be used to enhance memory, to understand and organize information for future use, and to be able to purposefully navigate in and interact with the world around us. *Embodiment,* or the immersion of body in both the physical field setting and the social environment of geologists at work, enhances organization of knowledge by geoscientists. Embodiment, or immersion in a field setting, imparts knowledge about how to interact with the natural world. (e.g., Goodwin, 1994, 2010). Physical actions of the body are directly connected to cognitive and memory functions. Frodeman (2003) argues that being able to see the relevant details in an outcrop "has little to do with native intelligence, or following a set of logical procedures. Rather it depends upon *knowing your way around* the topic, being oriented in conceptual space." By physically moving through a natural environment, students gain a knowledge of scale and spatial relations that are stored in memory that then become available for future use (Wilson, 2001, 2002; Montello et al., 2004). Embodied actions such as moving through space, seeing and manipulating objects, and gesturing to impart meaning is central to not only producing maps and other representations, but also knowing how to understand the inscriptions produced by others.

- In the field setting, students come into direct experiential contact with the raw materials of nature in their full, primal, and complex contexts. In the classroom setting, students work with distilled products of scientific investigations such as maps, diagrams, graphs, or idealized representative collections of rocks, minerals, and fossils, which are often presented as dismembered artifacts out of context, without distracting features such as alteration or weathering, and without benefit of full explanation of the rationale, assumptions, and limitations that have led to their construction. These representations of nature are referred to as *inscriptions*. The first inscription that transforms nature into representations is the most important because it is in this instance that the learner is making informed decisions about what is important and how to best record and communicate new ideas (Latour and Woolgar, 1979; Latour, 1987). Inscriptions are constructed to reduce complexity and to focus attention on a particular detail. When students learn from derivative representations, someone else has already done the work in deciding what is important. The field setting allows students to make their own informed decisions about what to observe, for what purpose, how to represent these observations, and how to interpret and ascribe meaning to their work.
- Learning in the field has a strong metacognitive component (Weinstein et al., 2000; Lovett, 2008; Wirth and Perkins, 2008; Petcovic et al. 2009) and impacts students' learning, as they must be self-aware of their approach to a given field task, self-monitor their progress, and self-regulate their actions as they may have to modify their approach when confronted with emerging problems, unexpected findings or inconsistencies.
- The field setting also provides a strong social learning environment where master-novice relations are established, peer-to-peer learning occurs, and students can engage the established "community of practice" through discourse of the discipline (orally and through gesture), learned behaviors, and selection and appropriate use of tools (e.g., Frodeman, 2003).
- Huntoon et al. (2001) and Elkins and Elkins (2007), among many others, report significant learning gains of geologic concepts by students who were involved with extensive field learning programs. It appears that investments of time, resources, and energy in field instruction produces the desired returns of positive learning outcomes.

The unique physical and social qualities of the field setting can be emphasized in the design and implementation of a field trip, and can complement or supplement other learning approaches used in the classroom or laboratory to gain a more complete and holistic understanding of the natural world.

LEARNING GOALS

There are many compelling reasons to invest the time and resources required to run an effective field tip, but perhaps the most important are to achieve expected learning goals and outcomes. Although there are many strategies used to design learning activities, the "backwards design" advocated by Wiggins and McTighe (2000) in which learning outcomes are identified, followed by development of evidence-based assessments and instruction and learning activities, works very well in the design of field-based instructional activities. The learning goals must be well-aligned (e.g., Boyle, 2007) with the context of learning: by audience, geological setting, and logistical constraints. Consider designing your next field trip around some of these general types of learning goals:

- Develop an experiential learning exercise (Kolb, 1984; Johnson et al., 1991; Millar and Millar, 1996) that includes inquiry and discovery (e.g., Field, 2003; Apedoe et al., 2006; Anderson, 2007). Use constructivist activities where students (re)discover for themselves the fundamental principles and concepts of Earth science, and actively construct knowledge by means of interaction of the student with the environment (Orion, 1993);
- Transfer basic content knowledge from the classroom or lab to the field setting. This employs relatively low levels of Bloom's Taxonomy (Bloom et al., 1956) and requires students to undertake tasks such as describing, identifying, listing, and recognizing objects or phenomena in the field (Table 1).
- As appropriate for the intellectual maturity of learners, engage higher order thinking skills that require more

sophisticated cognitive tasks, such as application, analysis, synthesis, and evaluation.

- Design a problem-based learning exercise that results in outcomes that can be applied to answering a geological question or issue of societal importance (e.g., Bradbeer, 1996).
- Help students develop "scientific habits of mind" (American Association for the Advancement of Science, 1989), e.g., formulation and testing of a hypothesis, reasoned use of evidence, prediction, openness to new ideas, curiosity.
- Skill mastery such as development of observational skills; descriptive skills (e.g., rocks, landforms); procedural skills (locating oneself on a map or navigating point to point, note taking, annotating sketches or photos); measurement skills (e.g., measuring a strike and dip with a Brunton compass, measuring a stratigraphic section); mastery of a field method or instrument (e.g., geophysical methods, stream gauging); and development of ancillary skills such as writing, quantitative skills, and graphing.
- Some learning goals may lie squarely in the affective domain and might include increasing students' motivation to learn, curiosity, or sense of awe and wonder about the world (e.g., Kern and Carpenter, 1984, 1986). Other aspects of the affective domain may address interpersonal goals that could be realized by utilizing cooperative and collaborative learning (Johnson et al., 1991; Kempa and Orion, 1996; Srogi and Baloche, 1997; Mooney, 2006). A survey of students' perceptions of field work in the UK concluded, "Field work is good" (Boyle et al., 2007).
- Metacognitive learning goals can be designed to help students "think as a geologist" and to be able to self-monitor (being aware of their own thinking) and self-regulate (e.g., make informed decisions) in the field. Field instructors can readily use "talk-alouds" on the outcrop to externalize what you are seeing, what you are doing, why you are collecting a particular sample or taking a strike and dip measurement at this place; this is a great way to help students become self-aware of what they should be thinking and doing in the field.
- There are also a number of learning goals that address big challenges to learning in the geosciences: temporal thinking, spatial thinking, and complex systems (Manduca et al., 2004). Related learning goals might include topics such as helping students to see process in geologic features that might otherwise appear to be static (e.g., rocks, landscapes), make reasonable interpretations of complex Earth phenomena from data that are incomplete, ambiguous and uncertain (e.g., Ault, 1998; Raab and Frodeman, 2002), and to integrate numerous independent lines of evidence toward a coherent and internally consistent interpretation.
- In sum, learning goals big and small can be formulated to help students "read the story of Earth" and to be able to "tell its story."

TABLE 1. BLOOM'S TAXONOMY OF COGNITIVE SKILLS WITH EXAMPLES OF APPLICATIONS TO LEARNING IN THE FIELD*

Evaluating
Makes value judgments about the quality of ideas, methods or outcomes; appraises, concludes, contrasts, discriminates, prepares critiques, defends or supports, explains, or justifies project outcomes.
Synthesis/Creating
Creates a conceptual structure from diverse components; organizes, rearranges or reconstructs, integrates multiple lines of evidence, compiles and prioritizes information, design a new experiment/procedure, plan for next steps.
Analysis
Divides information or concepts into component parts to reveal the underlying structure of the problem at hand; distinguishes between fact and inference, compare and contrast, discriminates, illustrates, infers constructs diagrams or other models.
Application
Uses information, concepts or methods in a new situation; applies content learned in classroom to field setting; ability to construct, compute, demonstrate, discover, manipulate, modify, or predict.
Comprehension/Understanding
Understands the significance of a task, ability to articulate the essence of a problem or task at hand; comprehends, explains, predicts, interprets, summarizes or translates information.
Knowledge/Remembering
Recall data or information; describes, identifies, lists, recognizes, classifies, or collects.

*Modified from *Bloom's Taxonomy of Learning Domains* (http://www.nwlink.com/~donclark/hrd/bloom.html).

ASSESSMENTS OF LEARNING IN THE FIELD

Assessment methods of student learning outcomes in field-based activities have traditionally been very similar to those used in the classroom and laboratory: pre- and post-activity tests designed to show learning gains; surveys (e.g., knowledge surveys, confidence logs); scoring of work completed as recorded in field notebooks or maps often using a rubric (e.g., completeness, neatness, essential information recorded; e.g., Pyle, 2009); and preparation of final written or oral reports. In addition to these traditional assessment methods, it is worth considering:

- Formative assessments that include observations of students at work in the field (using a rubric to record types of behaviors and activities that the students employ); interviews with the students in real time in the field asking "what are you doing," "what is interesting or important," or "why are you doing that?"; or even videotaping students in the field to record their actions for future analysis (and for a fun way to recall and share the field day with the students; Goodwin, 1994, 1995, 2000).
- Reflective exercises that can be completed at the end of each field day or at the end of the field project. These might include reflective journals on what was learned that day, what was interesting or important, or what new questions or problems arose. Alternatively, concept maps or concept sketches might be used to demonstrate the degree

to which students have mastered and integrated the essential components of the field exercise.

- Technology is increasingly being used to assess learning in the field. Maskall and Stokes (2008) report on the creation of Web sites to demonstrate final field products. Social media can be used to document daily field activities. Riggs et al. (2009a, 2009b) have used GPS instruments to track students' movements in the field to reveal their decision-making processes and the maps that were produced

Given the large investments made in field instruction in the geosciences, there is a surprising paucity of solid, evidence-based examples of effective assessment instruments and techniques. There is a real need to be able to demonstrate the ways and extent to which learning goals have been achieved with respect to mastery of concepts and concepts, skill development, and affective gains that result from field learning experiences. This is an area where more directed scholarly research is needed.

TEACHING ACTIVITIES IN THE FIELD

The choice of teaching activity in the field should be well-aligned with the learning goals and anticipated outcomes or learning products. Learning in the field encompasses a variety of activities ranging in scale from a single outdoor class activity (perhaps with a duration of only an hour or two) to sustained individual or group projects, short- or long-term in-residence programs, "capstone" field camps at the undergraduate level, and group or individual field projects that can produce novel research results conducted at the undergraduate or graduate level. Field instruction is commonly done: (1) as focused studies at a single site; (2) as part of a regional reconnaissance to investigate large-scale relations in a region; (3) to deploy and use dedicated instrumentation; (4) with a focus on disciplinary applications such as geophysics (e.g., May and Gibbons, 2004), hydrology (e.g., McKay and Kammer, 1999; Fryar et al., 2010), paleontology (Clary and Wandersee, 2008), and soil geomorphology (Eppes, 2009); and (5) in interdisciplinary programs (e.g., environmental studies—LaSage et al., 2006; Elkins et al., 2008; hydrogeochemistry—Carlson, 1999; watershed science—Pearce et al., 2010). For K–12 students and the general public, field experiences may include short trips to local sites, more extended field trips to a site of specific interest, and participation in informal educational activities hosted by civic organizations, or informal learning centers such as parks, museums and aquariums, and citizen-scientist programs. Butler (2008) recommends that these types of activities are particularly amenable for field instruction:

- setting student-led tasks;
- reinforcing scientific method through hypothesis-testing;
- developing integrative skills;
- problem solving, particularly through the interpretation of incomplete data sets and managing uncertainty;
- dealing with real-life, real-time interdisciplinary problems;
- showing the limitations of observations and measurements in problem solving; and
- developing self-reliance amongst students, taking personal responsibility for safety practices.

Whatever your learning goals, the learning by students will be much richer if the emphasis is on experiential learning that includes inquiry and discovery. What is discovery for students is often rediscovery of what is already known in the geologic literature. But it is still important for students to go through the steps of constructing their own knowledge. Discovery exercises may require a certain amount of scaffolding, and "guided discovery" may be needed to help initiate students into the practices of geoscience. But the field learning activities will provide an essential foundation to help students learn to think and work as geoscientists.

PLANNING AND LOGISTICS

Bob Dylan had it right: "And I'll know my song well before I start singing" (lessons learned, no doubt, from his roots in nearby Hibbing, Minnesota). Careful planning by the instructor, and preparation by the students, is essential for a safe and effective field trip.

Here are a few suggestions for instructors:

- Do a dry run of the field trip beforehand. Make sure you have a clear knowledge of the route, travel times between sites, and key features to be explored at each site.
- Do your own homework. Be familiar with the local geologic maps, cross sections, and literature.
- Prepare a clear itinerary so students know what to expect—intellectually and logistically. Provide all essential background information (readings, maps), and examples of what final learning products should look like.
- Have a contingency plan—stuff happens. But even if the primary plan is not possible, significant learning can occur by pursuing alternative opportunities or in the face of adversity.
- Safety first. Field work is an integral part of much of the geoscience profession, and safe practices that adhere to professional standards must be adhered to at all times in the vehicles and with boots on the ground. Make sure that first-aid equipment is available on-site, and that emergency contact numbers are known. Field trip safety guidelines and forms can be found at the On the Cutting Edge website: http://serc.carleton.edu/NAGTWorkshops/hydrogeo/field_trips.html; http://serc.carleton.edu/NAGTWorkshops/structure/field_forms.html
- Strive to make the field experience accessible to all students. Be aware of any disabilities that students may have, and make appropriate accommodation.
- Access issues: it is increasingly difficult to get access to field sites that are geologically instructive and logistically practical, and we simply must preserve the field sites we use for instruction. Be sure to contact public (Bureau of Land Management, USDA Forest Service) and private land managers to secure all appropriate permissions.

Infuse in your students an ethic of preservation of these special places. Some sites are appropriate for making collections, but if in doubt, keep the rock hammers in the van!

For students, preparation for the field experience is essential. The concept of "novelty space" (Orion and Hofstein, 1994; Rudmann, 1994; Hurd, 1997; Mogk, 1997) addresses students' concerns and uncertainty about three important dimensions: where am I geographically, what is the geologic context and what am I supposed to be doing in this setting, and personal comfort and safety. No significant learning can occur when students are unsure about where they are, what they are supposed to do, what the expectations are for learning outcomes, or if they have concerns about their personal comfort and safety. The extent to which novelty space can be decreased by preparing students for field experiences via preactivity assignments, slide shows, virtual field trips, road logs, demonstrations on how to use equipment, simulated experiences (Benson, 2010), etc., will have a great positive effect on potential learning outcomes (Falk et al., 1978; Orion and Hofstein, 1994; Mogk, 1997). Learning can be enhanced and reinforced during the field trip by use of programmed mobile audiovisual media devices (e.g., Elkins and Elkins, 2006; Elkins, 2009) to help orient students in their geographic and geologic spaces.

FINAL THOUGHTS

There are many solid reasons to encourage field instruction across the geoscience curriculum. It should be a pleasure and a privilege to share this amazing Earth with learners of all types. And a field learning experience should be safe, informative, and enjoyable for all. So, as you prepare for your next field trip, take a few minutes and reflect on:

- What learning goals do I hope to achieve?
- What are the expected learning outcomes or products, and how will I know if the learning objectives have been achieved?
- What should students know and be able to do as a result of the field experience?
- What type of field activities will best meet these objectives?
- Beyond the science, how can I help our students to become better scientists?
- What can I plan for and do to prepare the students, and to make sure that the field experience runs smoothly and safely?

Let's get out and learn! See you on the outcrop.

ACKNOWLEDGMENTS

Special thanks to my own mentors and classmates with whom I've had the pleasure to work with in the field, and to many generations of students who have helped me gain insights into effective field instruction. Chuck Goodwin introduced me to the importance of embodiment and inscriptions in learning in the field. Karl Wirth provided a review that greatly improved the quality of the manuscript.

REFERENCES CITED

American Association for the Advancement of Science, 1989, Science for All Americans: Washington, D.C., AAAS.

Anderson, R.D., 2007, Inquiry as an organizing theme for science curricula, *in* Abell, S.K., and Lederman, N.G., eds., Handbook of Research on Science Education: Mahwah, New Jersey, Lawrence Erlbaum Associates, p. 807–830.

Apedoe, X.S., Walker, S.E., and Reeves, T.C., 2006, Integrating inquiry-based learning into undergraduate geology: Journal of Geoscience Education, v. 54, p. 414–421.

Ault, C.R., 1998, Criteria of excellence for geological inquiry: the necessity of ambiguity: Journal of Research in Science Teaching, v. 35, p. 189–212, doi:10.1002/(SICI)1098-2736(199802)35:2<189::AID-TEA8>3.0.CO;2-O.

Benson, R.G., 2010, The Campus Mine: An Adaptable Instruction Approach Using Simulated Underground Geology in a Campus Building to Improve Geospatial Reasoning before Fieldwork: Journal of Geoscience Education, v. 58, no. 5, p. 253–261, doi:10.5408/1.3559688.

Bloom, B.S., Engelhart, M.D., Furst, E.J., Hill, W.H., and Krathwohl, D.R., eds., 1956, Taxonomy of Educational Objectives: The Classification of Educational Goals, Handbook I: Cognitive Domain: New York, David McKay Co., Inc.

Boyle, A.P., 2007, Using Alignment and reflection to improve student learning: Elements, v. 3, no. 2, p. 113–117, doi:10.2113/gselements.3.2.113.

Boyle, A., Maguire, S., Martin, A., Milson, C., Nash, R., Rawlinson, S., Turner, A., Wurthmann, S.L., and Conchie, S., 2007, Fieldwork is good: the student perception and the affective domain: Journal of Geography in Higher Education, v. 31, p. 299–317, doi:10.1080/03098260601063628.

Bradbeer, J., 1996, Problem-based learning and fieldwork, a better method of preparation?: Journal of Geography in Higher Education, v. 20, p. 11–18, doi:10.1080/03098269608709340.

Bryant, P.E., Tversky, B., and Franklin, N., 1992, Internal and external spatial frameworks for representing described scenes: Journal of Memory and Language, v. 31, p. 74–98, doi:10.1016/0749-596X(92)90006-J.

Butler, R., 2008, Teaching Geoscience Through Fieldwork: Geography, Environmental and Earth Sciences Subject Centre, Learning and Teaching Guide, http://www.gees.ac.uk/pubs/guides/fw/fwgeosci.pdf (accessed June 2010).

Carlson, C.A., 1999, Field research as a pedagogical tool for learning hydrogeochemistry and scientific-writing skills: Journal of Geoscience Education, v. 47, p. 150–157.

Clary, R.M., and Wandersee, J.H., 2008, Earth science teachers' perceptions of an autonomous fieldwork assignment in a nationwide online paleontology course: Journal of Geoscience Education, v. 56, p. 149–155.

Elkins, J.T., 2009, Using portable media players (iPod) to support electronic course materials during a field-based introductory geology course: Journal of Geoscience Education, v. 57, p. 106–112, doi:10.5408/1.3544239.

Elkins, J.T., and Elkins, N.M.L., 2006, Improving student learning during travel time on field trips using an innovative, portable audio/video system: Journal of Geoscience Education, v. 54, p. 147–152.

Elkins, J.T., and Elkins, N.M.L., 2007, Teaching geology in the field: significant geoscience concept gains in entirely field-based introductory geology courses: Journal of Geoscience Education, v. 55, p. 126–132.

Elkins, J., Elkins, N.M.L., and Hemmings, S.N.J., 2008, GeoJourney: A field-based, interdisciplinary approach to teaching geology, Native American cultures, and Environmental Studies: Journal of College Science Teaching, v. 37, p. 18–28.

Eppes, M.C., 2009, Introducing field-based geologic research using soil geomorphology: Journal of Geoscience Education, v. 57, p. 11–22, doi:10.5408/1.3544222.

Falk, J.H., Martin, W.W., and Balling, J.D., 1978, The novel field trip phenomenon: adjustment to novel settings interferes with task learning: Journal of Research in Science Teaching, v. 15, p. 127–134, doi:10.1002/tea.3660150207.

Field, J., 2003, A two-week guided inquiry project for an undergraduate geomorphology course: Journal of Geoscience Education, v. 51, p. 255–261.

Frodeman, R., 1995, Geological reasoning: geology as an interpretive and historical science: Geological Society of America Bulletin, v. 107, no. 8, p. 960–968, doi:10.1130/0016-7606(1995)107<0960:GRGAAI>2.3.CO;2.

Frodeman, R., 2003, Geo-Logic: Breaking Ground Between Philosophy and The Earth Sciences: Albany, State University of New York Press.

Fryar, A.E., Thompson, K.E., Hendricks, S.P., and White, D.S., 2010, Incorporating a watershed-based summary field exercise into an introductory hydrogeology course: Journal of Geoscience Education, v. 58, no. 4, p. 214–220, doi:10.5408/1.3534861.

Goodwin, C., 1994, Professional Vision: American Anthropologist, v. 96, p. 606–633, doi:10.1525/aa.1994.96.3.02a00100.

Goodwin, C., 1995, Seeing in depth: Social Studies of Science, v. 25, p. 237–274, doi:10.1177/030631295025002002.

Goodwin, C., 2000, Practices of color classification: Mind, Culture, and Activity, v. 7, no. 1-2, p. 19–36, doi:10.1207/S15327884MCA0701&2_03.

Goodwin, C., 2010, Things and their embodied environments, *in* Malafouris, L., and Renfrew, C., eds., The Cognitive Life of Things: Cambridge, McDonald Institute Monographs.

Huntoon, J.E., Bluth, G.J.S., and Kennedy, W.A., 2001, Measuring the effects of a research-based field experience on undergraduates and K–12 teachers: Journal of Geoscience Education, v. 49, p. 235–248.

Hurd, D., 1997, Novelty and its relation to field trips: Education, v. 118, p. 29–35.

Johnson, D.W., Johnson, R.T., and Smith, K.A., 1991, Active learning: cooperation in the college classroom: Edina, Minnesota, Interaction Book Company.

Kempa, R.F., and Orion, N., 1996, Students' perception of co-operative learning in Earth science fieldwork: Research in Science & Technological Education, v. 14, no. 1, p. 33–41, doi:10.1080/0263514960140103.

Kern, E., and Carpenter, J., 1984, Enhancement of student values, interests and attitudes in earth science through a field-oriented approach: Journal of Geological Education, v. 32, p. 299–305.

Kern, E., and Carpenter, J., 1986, Effect of field activities on student learning: Journal of Geological Education, v. 34, p. 180–183.

Kolb, D.A., 1984, Experiential Learning: Experience as the Source of Learning and Development: New Jersey, Prentice Hall, 256 p.

Krathwohl, D.R., Bloom, B.S., and Masia, B.B., 1973, Taxonomy of Educational Objectives, the Classification of Educational Goals, Handbook II: Affective Domain: New York, David McKay Co., Inc.

LaSage, D.M., Jones, A., and Edwards, T., 2006, The Muddy Creek project: evolution of a field-based research and learning collaborative: Journal of Geoscience Education, v. 53, p. 109–115.

Latour, B., 1987, Science in Action: How to Follow Scientists and Engineers through Society: Cambridge, Massachusetts, Harvard University Press.

Latour, B., and Woolgar, S., 1979, Laboratory Life: The Social Construction of Scientific Facts: London, Sage.

Lovett, M.C., 2008, Teaching Metacognition: Presentation at 2008 EDUCAUSE meeting, http://net.educause.edu/ELI081/Program/13300?PRODUCT_CODE=ELI081/FS03 (accessed June 2011).

Manduca, C., and Carpenter, J.R., 2006, Introduction to special issue on "Teaching in the Field": Journal of Geoscience Education, v. 54, p. 92.

Manduca, C., Mogk, D., and Stilling, N., N., 2004, Bringing Research on Learning to the Geosciences: Workshop report from a Wingspread Conference, http://serc.carleton.edu/files/research_on_learning/ROL0304_2004.pdf (accessed June 2011).

Maskall, J., and Stokes, A., 2008, Designing effective fieldwork for the environmental and natural sciences: Geography, Environmental and Earth Sciences Subject Centre, Learning and Teaching Guide, http://www.gees.ac.uk/pubs/guides/fw2/GEESfwGuide.pdf (accessed June 2011).

May, M.T., and Gibbons, M.G., 2004, Introducing students to environmental geophysics in a field setting: Journal of Geoscience Education, v. 52, p. 254–259.

McKay, L.D., and Kammer, T.W., 1999, Incorporating hydrogeology in a mapping based field camp: Journal of Geological Education, v. 47, p. 124–130.

Millar, M.G., and Millar, K.U., 1996, The effects of direct and indirect experience on affective and cognitive responses and the attitude-behaviour relation: Journal of Experimental Social Psychology, v. 32, p. 561–579, doi:10.1006/jesp.1996.0025.

Mogk, D., 1997, Field Notes, *in* Brady, J., Mogk, D., and Perkins, D., eds., Teaching Mineralogy: Mineralogical Society of America, p. 47–52.

Montello, D.R., Waller, D., Hegarty, M., and Richardson, A.E., 2004, Spatial memory of real environments, virtual environments, and maps, *in* Allen, G.L., and Haun, D., eds., Human spatial memory: Remembering where: Mahwah, New Jersey, Lawrence Erlbaum Associates, p. 251–285.

Mooney, S.J., 2006, A simple group work approach for effective field work: a soil sciences case study: Journal of Geoscience Education, v. 54, p. 74–79.

Orion, N., 1993, A model for the development and implementation of field trips as an integral part of the science curriculum: School Science and Mathematics, v. 93, p. 325–331, doi:10.1111/j.1949-8594.1993.tb12254.x.

Orion, N., and Hofstein, A., 1994, Factors that influence learning during a scientific field trip in a natural environment: Journal of Research in Science Teaching, v. 31, p. 1097–1119, doi:10.1002/tea.3660311005.

Pearce, A.R., Bierman, P.R., Druschel, G.K., Massey, C., Rizzo, D.M., Watzin, M.C., and Wemple, B.C., 2010, Pitfalls and success of developing an interdisciplinary watershed field science course: Journal of Geoscience Education, v. 58, p. 145–154, doi:10.5408/1.3544295.

Pessoa, L., 2008, On the relationship between cognition and emotion: Nature Reviews. Neuroscience, v. 9, p. 148, doi:10.1038/nrn2317.

Petcovic, H., Libarkin, J., and Baker, K., 2009, An empirical methodology for investigating geocognition in the field, in: Journal of Geoscience Education, v. 57, p. 316–328, doi:10.5408/1.3544284.

Pyle, E., 2009, A framework for the evaluation of field camp experiences, *in* Whitmeyer, S., Mogk, D., and Pyle, E., eds., Field Geology Education—Historical Perspectives and Modern Approaches: Geological Society of America Special Paper 461, p. 341–356, doi:10.1130/2009.2461(26).

Raab, T., and Frodeman, R., 2002, What is it like to be a geologist? A phenomenology of geology and its epistemological implications: Philosophy and Geography, v. 5, p. 69–81, doi:10.1080/10903770120116840.

Reynolds, S.J., Piburn, M.D., Leedy, D.E., McAuliffe, C.M., Birk, J.P., and Johnson, J.K., 2006, The Hidden Earth—Interactive Computer-based modules for geoscience learning, *in* Manduca, C., and Mogk, D., eds., Earth & Mind: How Geoscientists Think and Learn about the Earth: Geological Society of America Special Publication, v. 413, p. 157–170, doi:10.1130/2006.2413(12).

Riggs, E.M., Lieder, C.C., and Balliet, R., 2009a, Geologic problem solving in the field: analysis of field navigation and mapping by advanced undergraduates: Journal of Geoscience Education, v. 57, p. 48–63, doi:10.5408/1.3559525.

Riggs, E.M., Balliet, R., and Lieder, C., 2009b, Using GPS tracking to understand problem solving during geologic field examinations, *in* Whitmeyer, S.J., Mogk, D.W., and Pyle, E.J., eds., Field Geology Education–Historical Perspectives and Modern Approaches: Geological Society of America Special Paper 461, p. 323–340, doi:10.1130/2009.2461(25).

Rudmann, C.L., 1994, A review of the use and implementation of science field trips: School Science and Mathematics, v. 94, p. 138–141, doi:10.1111/j.1949-8594.1994.tb15640.x.

Srogi, E., and Baloche, L., 1997, Using Cooperative Learning to Teach Mineralogy (and other courses too!), *in* Brady, J., Mogk, D., and Perkins, D., eds., Teaching Mineralogy: Mineralogical Society of America, p. 1–26.

Storbeck, J., and Clore, G.L., 2007, On the interdependence of cognition and emotion: Cognition and Emotion, v. 21, p. 1212–1237, doi:10.1080/02699930701438020.

Weinstein, C.E., Husman, J., and Dierking, D.R., 2000, Self-regulation interventions with a focus on learning strategies, *in* Boekaerts, M., Pintrich, P.R., and Zeidner, M., eds., Chapter 22 in the Handbook of Self-Regulation: Academic Press, p. 727–747.

Whitmeyer, S.J., Mogk, D.W., and Pyle, E.J., editors, Field Geology Education—Historical Perspectives and Modern Approaches: Geological Society of America Special Paper 461, 356 p.

Wiggins, G., and McTighe, J., 2000, Understanding by design: Englewood Cliffs, New Jersey, Prentice Hall.

Wilson, M., 2001, The case for sensorimotor coding in working memory: Psychometric Bulletin & Review, v. 8, p. 44–57, doi:10.3758/BF03196138.

Wilson, M., 2002, Six views of embodied cognition: Psychometric Bulletin & Review, v. 9, p. 625–636, doi:10.3758/BF03196322.

Wirth, K., and Perkins, D., 2008, Learning to Learn: http://www.macalester.edu/geology/wirth/Learning.pdf (accessed June 2011).

Manuscript Accepted by the Society 27 July 2011

Printed in the USA