TOURING AND EXPLORING:

THE ROLE OF FIELD TRIPS IN GEOLOGY EDUCATION

by

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ABSTRACT

Evidence suggests that field trips to rock outcrops play a fundamental role in facilitating understanding of geological concepts. An introductory Physical Geology field trip was examined over four semesters to reveal the most effective ratio of professor-led touring versus student-centered exploring. The role of pre-trip frontloading activities and post-trip assessments and evaluations were also investigated. The efficacy of field trips utilizing a blend of all these elements is clearly demonstrated.

Introduction

Background

One of the most important goals I have for my introductory-level geology students is to give them the conceptual skills for solving geologic problems on their own. I want students to leave my course as individuals who can use their knowledge of geologic processes and logic to figure out the extended geologic history of areas they live in or visit. There are tremendous, epic tales lying in the rocks we walk over every day. I try to help students learn how to read those stories on their own. One venerable technique for developing these conceptual skills is the field trip. My sense is that field trips are an essential part of the geologic learning process. But do my students feel the same way?

The students described in this study were enrolled in my Physical Geology course at Northern Virginia Community College (NOVA) in Annandale, Virginia in the fall semester of 2008 and the spring semester of 2009. In teaching the course, I emphasized observations, hypothesis-testing, and interpretive skills. The class included a mandatory field trip to the rugged local hiking area called the Billy Goat Trail. This excursion served in many ways as the practical culmination of the class. However, in the fall semester, this 'culmination' was scheduled earlier in the semester than I might otherwise chosen, in an attempt to avoid cold weather. In the spring semester, I scheduled the trip in mid-April, which allowed the students a couple of weeks to compose their field trip paper before the end of the semester.

The students' ages, backgrounds, academic abilities, and motivations were diverse. As a community college in a highly international urban area, we draw students from dozens of countries ranging in age between high school students and senior citizens. NOVA has grown to be the largest institution of higher education in the Commonwealth of Virginia, serving the needs of this varied population. Some students enrolled in my geology classes because they are switching careers. Others were there because they had low grade point averages in high school. I have several students in each semester's class with documented learning disabilities. Another several enrolled as Honors students, who complete a special research project in geology at the same time as "regular" student duties. As a result of all this diversity, the classes were quite a mix of people.

On the field trip, I took my students out to areas with well-exposed rock outcrops like the Billy Goat Trail, and the students observe the rocks' characteristics and identify them. They made observations about superposition, cross-cutting relationships, and established relative geologic timing. Where radiometric dates are known, I provided them. Then the students were asked to interpret the whole day's worth of field work and make a coherent chronological geologic story out of all the data. I emphasized that the students make observations about rock outcrops and then interpret those observations in light of the skills and perspective we have been building in lab and lecture all semester. Many skills came into play, including rock and mineral identification, interpretation of those rocks in terms of depositional environment (if sedimentary) or orogenic/tectonic causes (if igneous or metamorphic), and correctly identifying the relative timing of geologic events. In addition, students made many "unprovoked" observations, which then served as fodder for discussion and interpretation.

Focus Question

My main research question was “What effect does the style of an introductory geology field trip have on student learning?” "Style" in this context refers to whether the field trip is being run as a guided tour or is more focused on student exploration and discovery.

Subquestion 1

What effect do pre-trip "frontloading" (a.k.a. "preview" or "orientation") activities / discussions have on student learning?

Subquestion 2

What effect to post-trip "summarizing" (a.k.a. assessment / "debunking") activities / discussions have on student learning?

Literature Review

In geology more than most sciences, field trips are seen as integral to developing a proper sense of space, scale, and time (Lathrop and Ebbett, 2006). Delaney (1967) suggested that “the field trip is education’s oldest technique; it is also one of the least understood” (p. 474). The use of field trips has been endorsed as being conducive to learning in general (National Research Council, 1999), and may be especially so for geology. Numerous studies have examined this educational relationship.

Through the years, a host of reasons have been offered in support of the investment of time and effort that field trips require. Knapp (2000) lists as advantages the retention of knowledge and an improved attitude towards the site of the trip. Mulligan (2004) notes that field trips offer “hands-on, real-world experience” (p. 4). Lathrop and Ebbett (2006) assert that “the essence of field experience is fundamental,” both for geology majors and for “anyone who is drawn to explore the enormity of earth history that scientific inquiry can reveal” (p. 165). In describing the integration of field work in geoscience studies at Washington and Lee University, Knapp, Greer, Connors, and Harbor (2006) claim that "learning in a hands-on setting is one of the best ways to reinforce topics learned in the classroom, to integrate academic and experiential learning" (p. 105).

The logical foundation for field trips is traditionally given as a list of benefits:

> Field experiences are an important part of the life of the geoscience student and professional. We take our students to the field to see fundamental relationships and to learn to observe, collect and interpret data. Field trips often form the social backbone of geoscience departments, bringing students and faculty together to learn. Field trips can be the highlight of an elementary student's year. Similarly, field trips are an integral part of the professional geoscientists ongoing professional development providing opportunities to see new and familiar field areas through the eyes of our colleagues and to wrangle over their interpretation...
>
> - National Association of Geoscience Teachers (2008).

Other benefits cited by field trip researchers include experience working with maps, diagrams, and field equipment (e.g. Pederson, 1978), socialization among colleagues (NAGT, 2008) and among students (Mulligan, 2004), and the development of a rapport between teachers and students. Additionally, other benefits include fostering a positive attitude towards science as a general concept, and positive attitudes towards specific field trip locations (Mulligan, 2004; Orion, 1989).

In reviewing the SEA Semester program, McClennan and Meyer (2002) valued a "combination of theoretical learning and practical experience" (p. 266). They write that many of their students report “the practical aspects demonstrated the relevance of the subject matter to their lives” (p. 268). Because SEA Semester takes place on a boat, it offers a full-immersion field experience (and an attendant minimization of distractions), but it is unusual among field experiences because of its extreme isolation and expense.

Returning to land-based trips, Manner (1995) notes that the benefits of field trips are not entirely limited to students. She points out that excursions add new “teachable moments” to the teachers’ repertoire, and that these “teachable moments” are less likely to occur in a classroom.

Nazier (1993) conducted a survey of 300 present-day scientists and engineers and asked about various reasons they had chosen their careers. He found that a large percentage of those surveyed cited an educational field trip as one of the primary motivators that drove them towards their ultimate career choice. Along similar lines, a survey of recent graduates from a geology B.S. program at Southwest Missouri State University revealed a groundswell of support from the alumni for the field experiences they had received as undergraduates (Plymate, 2005). Of those surveyed, 73.8% indicated that they are employed in geological careers. These alumni ranked field experiences as an average of 3.77 out of 4 in terms of essentialness (where 4 is “essential” and 1 is “unimportant and unnecessary”). In 104 responses, only 3 suggested that field trips be cut from the departmental budget (Plymate, 2005).

There are also negative aspects to be considered when preparing to lead students on a field trip. As reviewed by Kean and Enochs (2001), these include logistical hassles such as lack of planning time, bureaucratic red tape, transportation, as well as legal considerations (reluctance of schools to assume risk), cost, and student population size (large classes) with attendant issues of discipline and access. Anderson (1980) also pointed out that some students view field trips as “escapes from learning” rather than educational events rich in information and potential for understanding. Falk and Balling (1979) add these disadvantages: a break in routine, time spent in transit, and time away from other classes. In his discussion of fieldwork in introductory oceanography, Reynolds (2004) notes an intense amount of paperwork involved for instructors as an additional downside to field experience.

In her comprehensive review of field trip studies, Rudmann (1994) notes that effective field trip leaders are aware of a trio of considerations: pre-trip instruction, the novel setting of the trip, and the actual instructional methods used on the trip. The best trips are hosted by leaders who manipulate these variables to the educational advantage of their students. It may be these restrictive considerations that lead to one surprising finding that MacDonald, et al. (2005) reported: only half of surveyed geoscience teaching faculty employed fieldwork as part of their teaching strategy and half responded that they “never” employed fieldwork in their teaching.

Many workers have attempted to document and/or quantify the positive learning effects of field trip experiences. One technique for measuring success involves the use of pre-trip and post-trip exams or questionnaires. For instance, Pederson (1978) used pre- and post-tests to determine that key misconceptions relating to groundwater flow were diminished after a group of college freshmen with no previous groundwater experience had participated in a one day hydrology field trip. Similarly, Rodbell and Grenillion (2005) reported that their students “found outdoor field work to be essential for understanding” their course’s limnological focus (p. 497). They report a dubious endorsement offered by one student, who commented that “without the [field-based] labs, this course would have been useless” (p. 499).

Falk and Balling (1979) studied 425 elementary school students who went on science field trips. Testing the students at the end of the trip, after one month, and after six months, they found an increase in learning with an increase in number of examples of a particular phenomenon, and also an increase in learning corresponding with the novelty of the field trip setting. When the setting was sufficiently removed from their every-day routine, the researchers found that students were spending ~90% of their field trip time on the assigned activities. One of the longest-lasting effects showed that "positive feelings" towards the field trip site lingered, and that students voiced a desire to return to the site in the future (Falk and Balling, 1979).

Knapp (2000) also studied the effectiveness of elementary school field trips. Students from a rural elementary school (71 total) went on an environmental science field trip and were surveyed one month later and 18 months later. Knapp found that the students' memories were nonspecific and dissociated from academic knowledge imparted on the field trip. However, a strong majority (71%) expressed a desire to return to the site of the trip, and 81% specifically expressed an interest in learning more about the science they had "learned" on the trip (Knapp, 2000).

Some studies have compared field-trip-taking populations of students to other populations which do not get field experience. In an effort to meet enrollment demands in spite of limited lab space, Hoffman and Fetter (1975) offered an introductory geology course at the University of Wisconsin wherein students could opt for either a traditional lab section or an entirely field trip-based "lab" section. Since the program's inception in 1972, about 50% of introductory geology students opt for the field trip option, a substantial number of subjects. The researchers found that there was no discernible difference between the two populations in their understanding of the scientific method, but there were topical differences, such as the ability to identify minerals (better in the "lab" group) and an appreciation for the role of geology in every-day life (better in the "field" group) (Hoffman and Fetter, 1975).

Karabinos, et al. (1992) also noted that field trips are not uniformly more effective than classroom-based learning. They employed field-research-based projects for a population of undergraduate students in introductory geology courses. The students develop their own hypotheses, collect their own data, and interpret that data in small groups before presenting it to the class as a whole (and their professors). Karabinos, *et al.* (1992) state that "although this method is not efficient for transmitting information, it helps students…understand the importance of separating observations from interpretations [and] …appreciate how difficult it is to ask good questions" (p. 302). This is a perspective on science that cannot be taught directly, they claim, but must be experienced to be learned.

Kern and Carpenter (1986) presented an oft-cited study which compared two populations of undergraduate students. Both groups of students were enrolled in introductory geology courses at Southeast Missouri State University. One group of students engaged primarily in classroom activities based on a printed lab manual. The other population participated in field-oriented, on-site activities. At the end of the course, a comparison made between the two groups found that they exhibited statistically identical levels of "lower order learning" (factual recall), but the field-based group showed higher levels of "higher order learning" such as comprehension, application, analysis, and synthesis.

Among junior high school students, Folkomer (1981) found a similar pattern. He compared three groups of students: those who received lecture only, those who both listened to lecture and participated in laboratory exercises, and those who went only on field trips. When tested on observation questions, the field trip students performed significantly better than the other two groups, but there were no significant differences between groups when tested with interpretive questions. Though he did not test the basis for this difference, Folkomer (1981) believes "students were motivated to a greater extent by being in the field" (p. 75).

Action research has been an effective approach to examining field trips' efficacy. In a Montana State University MSSE capstone, Mulligan (2004) used interviews and pre- and post-tests to determine that field trips yielded a more integrated understanding of geology and biology among his middle school earth science students. Similarly, Peavy (2006) demonstrated that an on-site field experience raised environmental awareness among his middle-school science students.

A great many undergraduate geology programs offer field trips as an integrated part of their curriculum (e.g., Riecker and Dudley, 1971; Schwartz, 1988; Spencer, 1990; Karabinos, *et al*., 1992; Thomas, 2001; Ambers, 2005; Lathrop and Ebbett, 2006). Some undergraduate programs have taken field trips to exciting extremes, including integrated field courses in the Bahamas (Eves, *et al.*, 2007) or a semester-long road trip around North America (Elkins, *et al*., 2008; Elkins and Elkins, 2007). When knowledge gain is measured with pre- and post-testing, these courses show a measurable improvement. For instance, Elkins and Elkins (2007) utilized a Geoscience Concept Inventory (Libarkin and Anderson, 2005) to assess how efficacy of their extended "Geojourney" field course. Though not statistically significant due to the small class size of 30 students, Elkins and Elkins (2007) report an increase in mean scores on the Geoscience Concept Inventory from 51.6±12.4 pre-trip to 63.5±11.4 post-trip. This indicated that conceptual understanding had been enhanced by the trip experience (Elkins and Elkins, 2007).

The issue of time spent in vehicles has vexed several researchers. Students often spend this time sleeping or engaging in non-field-trip-related activities. One researcher, Locke (1989) reported positive effects by getting students out of vehicles and onto bicycles. He describes a

1600-km bicycle tour of California and Nevada as a geology field trip in which "the travel, not the stops, is the major teaching tool" (p.107). Noel and Malone (1971) endorsed the idea of videotaping field trips for later "rerun" playback. On their epic "GeoJourney" trip, Elkins and Elkins (2006) used an audio/video system to play taped geology programs of relevance to the trip, and also to deliver PowerPoint presentations, while the van was in motion down the highway. Student evaluations reflected positively on this innovation, with students the background knowledge helped them to focus on the relevant details when they were actually at an outcrop.

A field trip does not need to be superlative to be effective. Smaller geological "field camp" type experiences have yielded similar results. For instance, Huntoon, *et al.* (2001) report improvements in geological understanding among undergraduates after a two-week field experience, as measured by pre- and post-trip testing (see also Schwartz, 1988; Karabinos, *et al*., 1992; Lathrop and Ebbett, 2006; Spencer, 1990; and Thomas, 2001 for diverse examples of "field camp" type field trips across the U.S.).

Both Spencer (1990) and Lathrop and Ebbett (2006) emphasize that geological field trips should begin early as a stimulant for student interest, rather than their traditional placement as a "capstone" at the end of a geological education unit. Lathrop and Ebbett (2006) state that they "have never encountered a student whose world view was not profoundly affected by this experience" (p. 170). Neff (1977) concurs, with a declared three-fold increase in geology majors after introductory-level field courses began to be offered. Darby and Burckle (1975) join Lathrop and Ebbett (2006) in reporting positive results by letting students take the lead in determining research questions and engaging in field trip planning.

To improve the efficacy of field trips on geologic learning, a host of strategies have been employed. Rudmann (1994) offers a list of advice (p.140) including "create goals and objectives which justify the purpose of the field trip" and "allow students to experience the excitement of exploration and discovery." She also endorses the efficacy of post-trip materials, projects, or activities to reinforce and transfer knowledge (Rudmann, 1994).

In contrast to the findings of Falk and Balling (1979), Orion (1989) and Orion and Hofstein (1991) suggest that a primary impediment to learning on field trips is what they call "novelty space." In studies of 256 Israeli high school students, they note that while students feel positively about the field trip location, a lack of familiarity with the new environs causes a majority of the students' attention to be devoted to finding their way through the novel landscape. As a result, a minimal amount of attention is left over for learning content. Orion and Hofstein (1991) define three factors which contribute to "novelty space" variations: (1) knowledge type and level, (2) familiarity with the field trip area, and (3) psychological preparedness. The opposite nature of these findings with respect to the elementary-aged subjects of Falk and Balling (1979) may be attributable to the age groups involved: Orion and Hofstein's (1991) subjects were engaging in higher-level learning. At that level, the researchers were focused more on factual retention than "positive feelings about the field trip locale" (e.g., Falk and Balling, 1979, p.7).

In an effort to control for this variable, Kean and Enochs (2001) took their population of students (who were themselves science teachers) to their program's field areas (four beaches on Lake Michigan) multiple times. First, they were brought in an introductory look around, and then they returned twice more for data collection and analysis. The program sponsors (Kean and Enochs, 2001) specifically adopted this strategy as a means of making the participants familiar with the new locations on a basic, exploratory level before they were asked to evaluate it geologically.

If only one visit to the site is possible, the work of Delaney (1967) suggests that a pre-trip introductory lecture may serve to minimize novelty by preparing the students for what they will see and what orientation talk scored significantly higher on post-tests.

Several studies examined the effects of reflective activities on enhancing student learning. Elkins and Elkins (2007) claim that end-of-the-day campfire discussions helped "seal in" knowledge and understanding gained through the day's field activities. Stanseco (1991) emphasized the use of reflective writing in personal journals among his students on field trips. The results are unique to each student, and representative of their diverse levels of background knowledge and experience. Ricker and Dudley (1971) also report enhanced student success via evening "recap"-style conversations.

Buddington (2006) used another variety of writing – field reports – to assess his students' understanding of a series of field exercises in the Pacific Northwest. The first of three reports is graded in great detail: "To say the least, a considerable amount of red ink is used in the grading of the first report," Buddington said (p.586). This initial investment of copious feedback improved later observation, interpretation, and writing on the part of the students. Over six semesters of running this writing-intensive field class, Buddington (2006) reports a weighted average increase of +2.5% over the course of the semester's three reports.

Another suggested strategy for success on field trips was artistic. Both Huntoon, *et al.* (2006) and Karabinos, *et al.* (1992) encouraged student sketching of field outcrops prior to any explanation by trip-leading professors. The idea was to emphasize observations and spatial understanding as a foundational step which could later be expanded through interpretation.

A mix of student types may be a hindrance to learning, due to diverse “starting points” and various levels of background knowledge, but both Neff (1970) and Thomson, *et al.* (2006) report that more experienced students will spontaneously “mentor” less experienced students. Mixing student populations may therefore be an effective strategy for lessening the teacher’s workload and increasing inter-student discussion.

In all, a wealth of published literature has documented the challenges and benefits of field trips, especially in the geosciences. As science is a testable enterprise based on verifiable observations, the utility of geologic field trips establish both professional skills and a general sense of knowledge and perspective on the Earth’s history. As Zen (2001) put it, “nothing can truly replace hands-on experience where one could freely explore and, in real time, check out the instructor’s story” (p.8).

Methods

My treatment was to try various styles of leadership on my different field trips, and on different iterations (runs) of the same trip. Sometimes I ran the trip like a tour guide, and sometimes I put the investigative focus entirely on the students' discoveries, exploration and questions. To address my subquestions, sometimes I used frontloading activities before the trip, and sometimes I did not. Sometimes I used post-trip wrapping-up summarization activities, and sometimes I did not (or could not, due to time constraints). I varied the combination of techniques so that students had the opportunity to compare and could comment on what was most useful to them. The thinking here was that perhaps a certain combination or “cocktail” of techniques is most effective. For instance, over the course of the study, I became convinced of the usefulness of an end-of-trip activity wherein students were given several dozen strips of paper with geologic events written on them. They needed to use their observations and understanding, as well as a healthy dose of teamwork, to put the strips in the proper geologic order. This activity is now a standard part of my practice. As the study progressed, I found an optimally-effective blend, but continued to monitor its efficacy through student data.

To get a sense of the utility of the field trip, I collected several types of data over four semesters. On the trips, I made informal observations of the students' behavior. Each semester, I also administered a Pre-Trip Survey and a Post-Trip Survey via the online surveying website Survey Monkey (Appendix A). Additionally, I interviewed a subset of the class about the field trip (Appendix B). Each semester, the number of students interviewed ranged between 10 and 16. In my office, in the lab, or on the phone, I spoke to each student for about 10 minutes. I also used photography of students on field trips, participant observations where I act as an active participant observer, particularly of student explorations and an end-of-trip summarizing activity involving the ordering of geologic events, informal interviews, a comparative analysis of students' rubric-based scores on post-trip papers (Appendix C), and at the end of one run of the field trip, I had each student complete a "Muddiest Point" assessment (Angelo and Cross, 1993; Appendix D).

To corroborate my sources, triangulate my data sources, and validate my conclusions for these different questions, I collected a multitude of different kinds of data (Table 1).

Table 1. Triangulation of data sources.

Research topic	Data sources			
"Tour" vs. "explore"	Student surveys	Participant observations	Interviews (formal & informal)	Photography
Frontloading	Student surveys	Participant observations	Interviews (formal & informal)	
Summarizing	Student surveys	Participant observations	Interviews (formal & informal)	Muddiest point; Ordering activity

Data and Analysis

The comparison of students' self-assessment of geologic skills from the Pre-Trip Survey to the Post-Trip Survey is striking. Before the trip, only 14% of surveyed students (n=42) in my Fall 2008 Physical Geology class identified field trips as being the way that they best learned geology. After the field trip, this number increased to 34% (n=35). In the Spring 2009 semester, a new set of Physical Geology students showed the same pattern: before the trip, 24% of the students (n=38) claimed field trips as being the way that they best learned geology. After the trip, 43% made the same claim (n=23). Furthermore, there was a marked reduction in all other categories, except for "listening to lecture" (Table 2)

Table 2. A comparison of survey results for Physical Geology students' self-evaluation of how they best learn geology, as polled before and after the class field trip, Spring 2009 semester. The results show a significant shift from non-lecture techniques before the trip to field trips, once they had experienced a field trip. Lectures remained a majority choice both before and after the field trip. The majority of responses for each poll are highlighted in yellow.

How do you learn geology best?	Before (*n* =38)	After (*n* =23)
By reading the textbook	3%	4%
By watching television programs	11%	9%
By listening to lectures	45%	43%
By performing lab exercises	26%	13%
By going on field trips	24%	43%
By surfing the internet	8%	0%

Overall perception of their skill set also increased in the Fall 2008 semester (Table 3). In comparing the survey results from before and after the trip, a clear shift can be seen towards an increase in students' perception of performance. Without exception, every surveyed skill shows gains in student self-assessment. Before the trip, five skills had 0 "excellent" responses. After the trip, all but one had some students self-assessing as "excellent." Before the trip, there were two surveyed skills where a majority of students ranked themselves as below average, and nine skills with a majority of students self-assessing as "about average." After the trip, none of the skills had a majority of students self-assessing as below average, and the "about average" number dropped to four: mineral identification, understanding plate tectonics, evaluating tectonic scenarios from local rocks, and formulating and testing geologic hypotheses.

Table 3. A comparison of survey results for Physical Geology students' self-evaluation of geologic skills before and after the class field trip, Fall 2008 semester.. The majority of responses for each skill are highlighted in yellow.

Fall 2008	**Before** (*n* =42)					**After** (*n* =35)				
How would you rate your skill level at the following?	Awful	Worse than most, better than some	About Average	Better than most, worse than some	Excellent	Awful	Worse than most, better than some	About Average	Better than most, worse than some	Excellent
Mineral identification	7%	14%	50%	29%	0%	3%	9%	54%	31%	3%
Rock identification	5%	14%	55%	26%	0%	3%	6%	43%	46%	3%
Igneous rock interpretation	5%	14%	62%	19%	0%	3%	6%	43%	46%	3%
Sedimentary rock interpretation	5%	17%	57%	19%	2%	3%	6%	40%	43%	9%
Metamorphic rock interpretation	5%	14%	69%	12%	0%	3%	3%	40%	49%	6%
Ordering of geologic events (relative dating)	8%	43%	38%	13%	0%	3%	6%	29%	56%	6%
Understanding plate tectonics in general	2%	10%	41%	31%	17%	3%	0%	37%	26%	34%
Evaluating plate tectonic scenarios from local rocks	7%	45%	38%	7%	2%	3%	11%	49%	34%	3%
Formulating and testing geologic hypotheses	5%	38%	48%	7%	2%	3%	14%	49%	34%	0%
Understanding landscape change	7%	14%	57%	17%	5%	3%	6%	29%	57%	6%
Understanding river processes	5%	32%	46%	17%	0%	3%	0%	29%	60%	9%
Ability to write	5%	5%	29%	34%	27%	3%	6%	17%	49%	26%
Physical fitness and hiking ability	2%	7%	21%	31%	38%	0%	3%	20%	34%	43%
Comfort level outdoors	0%	5%	24%	27%	44%	0%	3%	14%	26%	57%

On the trip, I observed students' engagement with the subject matter through their dedicated effort at examining the rocks and level of participation in discussions. When one student would provide a correct identification or recall a process discussed in class from several weeks ago, there was a display of satisfaction on the successful student's face and congratulations from his or her peers. From the perspective of the instructor and trip organizer, this was very gratifying to witness.

These gains and observations are further corroborated by student statements in surveys and in post-trip interviews. For instance, one student said, “The Billy Goat Trail really changed the way I look at geology. Before, what I did was memorize. I didn’t really understand the relationship between sedimentary and metamorphic rocks.” At the end of the trip, students overwhelmingly indicated that one of the main things they gained from the field trip was a better understanding of how rocks form and change through time: 41% (N=44) listed a rock-formation answer for the one thing they understood better as a result of the field tip. The most common example they offered of this was the migmatite outcrop, an example of a rock that started off as sedimentary, was altered to become metamorphic due to mountain building processes, and then heated up enough that it began to melt, generating igneous granite. In the interviews, the migmatite was frequently mentioned as well. One student told me, “That encapsulates the whole process. It’s a freeze-frame of the basics of geology.” Without sarcasm, another student, said, “It really touched me, how those things happen in a rock.”

The Spring 2009 semester saw similar gains (Table 4). Before the trip, a striking majority of the students ranked themselves as “about average” in most geologic skills.

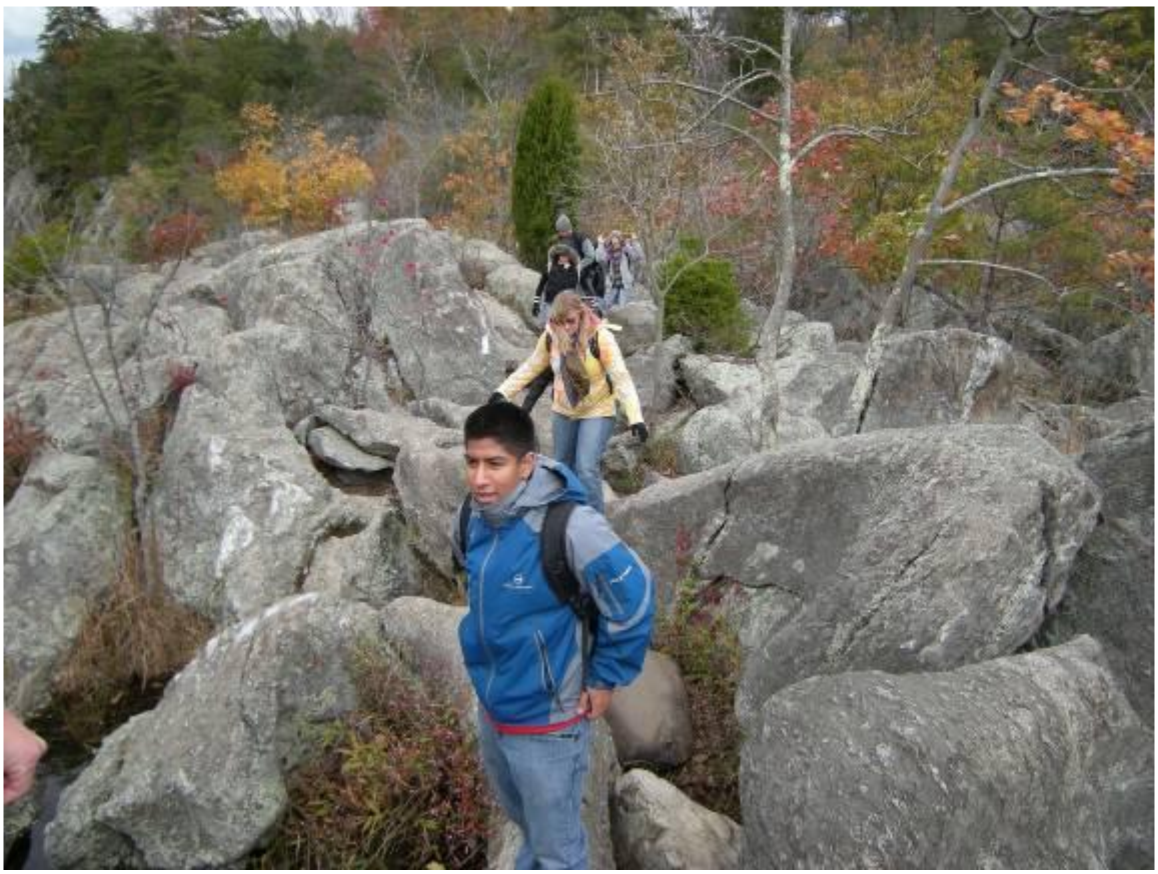
Table 4. A comparison of survey results for Physical Geology students' self-evaluation of geologic skills before and after the class field trip, Spring 2009 semester. The majority of responses for each skill are highlighted in yellow.

Spring 2009	Before (*n* =38)					After (*n* =23)				
How would you rate your skill level at the following?	Awful	Worse than most, better than some	About Average	Better than most, worse than some	Excellent	Awful	Worse than most, better than some	About Average	Better than most, worse than some	Excellent
Mineral identification	0%	16%	47%	26%	11%	0%	4%	44%	39%	13%
Rock identification	0%	13%	61%	21%	5%	0%	4%	44%	39%	13%
Igneous rock interpretation	3%	11%	54%	27%	5%	0%	4%	48%	35%	13%
Sedimentary rock interpretation	3%	11%	42%	37%	8%	0%	4%	30%	48%	17%
Metamorphic rock interpretation	3%	16%	41%	38%	3%	0%	9%	35%	39%	17%
Ordering of geologic events (relative dating)	3%	3%	55%	37%	3%	0%	13%	30%	30%	26%
Understanding plate tectonics in general	0%	5%	40%	32%	24%	0%	4%	26%	39%	30%
Evaluating plate tectonic scenarios from local rocks	0%	16%	63%	16%	5%	0%	9%	35%	39%	17%
Formulating and testing geologic hypotheses	0%	16%	51%	30%	3%	0%	4%	52%	35%	9%
Understanding landscape change	0%	8%	53%	25%	14%	0%	0%	35%	44%	22%
Understanding river processes	0%	14%	41%	35%	11%	0%	0%	37%	27%	37%
Ability to write	0%	5%	24%	34%	37%	0%	0%	22%	26%	52%
Physical fitness and hiking ability	0%	3%	19%	43%	35%	0%	0%	13%	35%	52%
Comfort level outdoors	0%	0%	16%	22%	62%	0%	0%	4%	22%	74%

Exceptions to this pattern included only the ability to write, a non-geological skill, and physical skills: hiking ability and comfort level outdoors. After the trip, surveyed students self-assessed as improved in seven of the formerly-"average" categories: sedimentary rock interpretation, metamorphic rock interpretation, relative dating, understanding plate tectonics, evaluating plate tectonic scenarios from local rocks, understanding landscape change, and understanding river processes. Participating students also self-assessed higher in physical fitness in the Post-Trip Survey.

The Post-Trip Survey (Appendix A) also asked students for their favorite moments on the trip. These responses were divided between several major categories. Among those surveyed the most common response was that they most appreciated the physically-challenging sections of the trail ("Pothole Alley" and "the Traverse"), which require a lot of concentration to navigate (Figure 1). In Fall 2008, 35 of the students completed the post-trip survey. Of those, 15 listed either Pothole Alley or the Traverse as their favorite moment. On the trip, these sections of the trail typically inspire comments like "Wow, this is really intense!" or just the sound of jaws dropping when they first see the Traverse (Figure 2).

Figure 1. Students navigating "Pothole Alley" on the Billy Goat Trail. The extremely uneven nature of the terrain demands attention that might otherwise be available for learning geology. On the other hand, this appears to be balanced out by their sense of fun and adventure.



When students were asked whether, considering the pros and cons, the field trip was a worthwhile experience for learning geology, they unanimously affirmed its value, sometimes with superlative comments. For example, one student responded, "It helped connect the dots of what we learned in lecture and the real world." Another student enthusiastically typed, "What a worthwhile experience! I am more comfortable naming rocks and its [sic] mineral composition and I also have more respect and pride for the [Billy Goat Trail].” Several students compared the field trip experience to laboratory exercises back on campus. One said, “It’s nice seeing exact examples during lab, but I guess I didn't think that realistically, I would see those types of things outside of class, so it was great.”

Figure 2. Students climb “The Traverse,” a steep and physically challenging section of trail that rated highly among their favorite memories of the trip.

Most of the students I interviewed felt that field trips are an important part of the geological learning process. Of the 25 I spoke to over two semesters, 18 claimed that the trip helped them apply what they learned in lecture and lab. A student in the Fall 2008 semester told me that “it helped me a lot, actually, to see how a rock is and identify it. In lab, we see a lot of little samples. But out there we saw a lot of big samples; how they really are. That went into my mind more than little, little, little ones." Another student told me that he appreciated watching the process of geology unfold. "It's like instead of seeing the box score of a football game, you're actually watching the [whole] game," he said. The detailed insight into how geology works helped him engage with the subject.

In the interviews, I explored the issue of which elements of a field trip are more effective: the pre-determined "tour" of the site by the instructor or a less-structured individual exploration of the site on the part of the student. I had expected to hear that students preferred self-directed exploration (since that is what I prefer), but I was surprised to find that many appreciated the "tour" aspect. A consistent theme from the interviews was that they appreciated my organization of the trip. For example, one student told me, "The order of the sites was very good; each leads to the next. Looking back, everything bunches together into one big, beautiful story."

Another student expressed something similar about his trip in the Fall 2008 semester. Our local geology is complicated, and it's difficult to pay attention to the minerals and structures in a rock when students are just trying to keep from falling off into the river (e.g., Figure 2). "You know that trail like the back of your hand," he told me. "You knew where the best examples are located. I appreciated that it was logistically coordinated so that we would end up in a good spot to have lunch." In the Spring 2009 survey, a student noted that, "There are many incredible things to see if you know what you're looking at or for." In an interview, a student said, "It kind of made you appreciate how hard it would be to try and figure out the geology. We passed by thousands and thousands of rocks, but very few added to the story." Multiple students expressed this idea, the sense that they would have been overwhelmed if they had been out there on their own without a guide to cue them in to important outcrops.

Four themes emerged from the data: (1) that field trips are an important part of the geological learning process, (2) that the best geology field trips involve elements of both instructor-lead explanation and student centered exploration / discovery, (3) that geology field trips impart a larger 'sense of place' beyond simply teaching science concepts, and (4) that reviewing the trip afterwards is an important activity for cementing observations and interpretations into a comprehensive sense of conceptual understanding.

The survey results indicating the students' unanimous agreement of the trip's value were affirmative evidence that field trips are valuable. I sometimes worry that I am imposing my own learning bias on the students by forcing them on these field trips. After all, I am a geologist today because I was attracted to the large number of field trips in my undergraduate geology major. But this study shows that it isn't just me: My own students feel that same way. "I think it was awesome to put perspective on how all geologic events overlay on one another," one student told me during our interview. "You can't tell the order in lab [with disarticulated specimens], but walking around outside in a couple of hours, you can put it together." Another student was more effusive: "It was amazing. I had trouble with igneous and metamorphic rocks [in lecture and lab], but ever since the field trip, it's all come together. I have a better understanding of the rock cycle."

An additional source of data on this issue came unexpectedly from archival material. On NOVA-issued general end-of-the-semester student evaluations of the course from the Fall 2008 semester (which I received back halfway through the Spring 2009 semester), 21% (N=55) said that out of the whole class, they liked the field trip most. Note that on an assessment which was not initiated by me, nor specifically mentioned the field trip, over a fifth of the class spontaneously mentioned the field trip as the best part.

The data did not yield universal accolades, however. I asked students to critique the trip, and they offered many suggestions that ranged from the difficult (fewer people, longer trips, shorter trips, multiple trips per semester), to the easy (making it clear when it was essential to take notes). These suggestions are all ideas I inherently agree with, and I only do things otherwise due to the logistical constraints of my job. Perhaps tangentially, the act of asking students to critique your performance face-to-face can yield a new spirit of cooperation. We are engaged in a mutual effort to educate them in geology, and I like how inviting critique fosters a sense of 'all being on the same team.'

Regarding the second theme, the question of whether it is better for students to "tour" or "explore," I found that most students preferred a blend of both. While some interviewed students called attention to the two-minute rock-identification exercise as the moment they felt most connected to the subject, they also expressed appreciation for not having to figure everything out themselves. The Atlantic Piedmont is a geologically complicated place, and it can help to have a guide to focus one's attention. One student found this to be advantageous: "[We] didn't have to look around and find stuff; You knew were they were and where to point them out." One of my most highly metacognitive students really appreciated focused exploration, a technique I tried for the first time this fall. She said "I liked it when you told us 'Walk down the trail until you see a new-looking rock.' That forces us to be aware of the situation rather than just following along like lemmings."

Student-directed exploration took place in numerous ways. Sometimes I initiated a session, such as the "watch for a new rock up ahead" example provided above, or when we first get down to the rocks, and I tell the students to take two minutes and make two observations about the rocks. There, I observed students pointing out interesting features to one another, as in Figure 3.

Figure 3. Students explore rock outcrops and share their discoveries with one another. Here, Daniel points at an apparent anticline he has found and shows it to Rob.

Figure 3 shows a moment of discovery from the Spring 2009 trip: student Daniel sharing a discovery with another student, Rob. It looked to Daniel like an upturned fold called an anticline. Rob then investigated the outcrop, and proclaimed it to be “the real deal.” The outcrop was then shared with the rest of the class and used as a fundamental piece of evidence in interpreting the history of the region’s rocks. Anticlines form due to differential stresses, like those resulting from mountain-building. This pattern-recognition by Daniel, followed by confirmation from Rob and some discussion facilitated by me led the class to an important conclusion: these rocks have experienced mountain-building in the past. Another example of exploration also came later in the trip. Unlike the first one, it was not prompted by me. After we had discussed the formation of potholes (cylindrical holes “drilled” into the bedrock by vortices in the river current), one student took a moment of downtime and poked around in a pothole using the scientific equipment close at hand: “I stuck a stick down one,” he said. “It went down really far! I thought, ‘Whoa… this formed from rock!’” Literally probing the mysteries of nature, he gained a perspective he would otherwise have missed.

Another aspect of a larger sense of group coordination was one I had not considered. One student who is not especially ‘outdoorsy’ appreciated that the group was kept as a group. As the leader, I made sure everyone had caught up before we discussed new outcrops, and she liked that. “That was reassuring,” she said. “It was like ‘I’m taken care of, even if I fall behind.’” Another student noted that there were numerous bottlenecks on the trail which forced the group to spread out. She told me that it was comforting to know she wasn’t going to miss any key information just because she was at the end of the line. A different student noted that the field trip had a sense of ‘groupness’ that was absent in the classroom. “It felt more like we were a team, more connected. You were like one of the guys out there. It was easier to learn, listen, and take notes,” he said.

The third theme to emerge was how geology was not just a topic limited to the classroom. It was real, out there in the real world, underfoot and everywhere. Many students expressed astonishment at how rich our local geologic record was. They had been oblivious to it, and the trip opened their eyes and expanded their perspective. The trip gave them a deepened sense of the place where they lived. “If you didn’t know geology, you wouldn’t know any of it,” one student said about her Fall 2008 trip. Referring to the insights he gained, a Spring 2009 student told me, “I went there [the Billy Goat Trail] again after our trip. It took me thirty minutes longer; I was paying more attention.”

My favorite example of the field trip’s ability to enhance a student’s sense of place was from an average student who has not been particularly engaged with class in the Fall 2008 semester. She told me, “I like how it’s in our area and it’s something I can respect about our environment. My cousins in California think Virginia is all plantations and junk. I’m proud to live here now. ‘We have this and this and this, and you guys [the cousins] don’t!’” Reveling in northern Virginia’s geologic diversity, she swooned, “It’s selfish to say, but we have it all. Pieces of the Blue Ridge, rocks of the Piedmont; we have everything.”

The final theme that emerged from this batch of data was that end-of-trip reviews were useful. Due to time constraints, one of my runs of the Fall 2008 field trip had time for an end-of-trip ‘recap’ session and the other did not. Several students claimed it helped them “fill in the gaps,” and reassured them that they had not inadvertently missed any important notes from the trial. One student told me that the summarizing session, “reiterated what you were listening to and gave you a better chance of understanding. It forces a moment of panic; makes you pay attention and think.” However, some students were on the trip without enough time for an end-of-hike review. One is a believer in the power of review, and she thought it would have been a useful addition to the field trip. She said, “it’s crucial to knowledge sticking, especially for those who wouldn’t review on their own.” Another noted the half an hour of traffic we had to wade through to get back to campus from the Billy Goat Trail, and said, “It probably would have been… nice to have a summary. Maybe on the ride home, it would have given us something to think about and discuss.”

A student in the Spring 2009 semester indicated that the review activity where students must order a series of geologic events written on little strips of paper was a “surprise” and a “challenge,” but that it was really useful “to those who participated.” On the same trip, another student had a different perspective: he noted that the little strips of paper were easily disturbed by the wind, plus he and his fellow students were annoyed by clouds of gnats which pestered them during the activity. Finally, another student noted that it was “really helpful to have the whole timeline laid out. Someone [took a digital photograph and] posted it online, and that helped too. I thought that was a pretty good idea.”

One of the ideas to emerge during student interviews at the end of the Fall 2008 semester was the idea of peer review. Because I evaluate the students based on a field trip paper, I want them to be able to write a paper that cleanly expresses their understanding without getting bogged down in grammatical errors. I also want them to use the writing of the paper as an opportunity to reflect on and synthesize their knowledge of Billy Goat Trail geology. For example, during the Spring 2009 interviews, student Bryan told me that he felt most connected to the subject matter while he was writing the paper, not while he was actually out on the field trip. “Field trips are fun,” he said, “but when it comes time to write the paper, you really have to buckle down. It forces you to retain the material because you’re going over it so much.”

I have been in the habit of encouraging students to submit a rough draft to me, which I then edit and comment on, returning it to the students for revision before the final, graded draft. However, this takes a lot of extra time and effort on my part. At the end of the Fall 2008 semester, a student suggested that perhaps students should review other students’ rough drafts. Based on this feedback, in the Spring 2009 semester, I instituted a student-centered “peer review” process. The idea was to (a) take some of the editing workload off of me, and (b) give students an additional opportunity to reflect on the field trip while (c) receiving constructive criticism of their papers before they submitted the final draft for a grade. Using Blackboard, our online ‘courseware’ platform, I set up a system where students submitted rough drafts to two of their classmates, who were then supposed to read and comment on them. However, it did not work completely smoothly. Some students missed the field trip, some students went on the trip but failed to write a rough draft, and some wrote a rough draft but failed to comment on other students’ rough drafts submitted to them. Keeping track of who met and did not meet all these responsibilities was a new task for me, fully the equivalent of reading and commenting on the papers myself. In addition, students pointed out that they were not necessarily sufficiently knowledgeable to offer geologic corrections to their peers. When surveyed, the Spring 2009 students were evenly split as to whether the peer review process was effective, semi-effective, or ineffective, with 32% to 34% of the students in each of those three categories. One student told me, “I’m not an expert in geology. I’m not confident in my ability to dispense proper information. And I don’t like being critical.” While well-intentioned, the process had numerous failings. From my perspective, this peer review process did not work well enough to repeat it in a future semester.

Value

All told, this study has affirmed my decision to engage in the logistically laborious business of planning and organizing a field trip because of the rich intellectual understanding that students gain. Increases in students’ assessment of their own skill levels were corroborated by my own observations of their behavior and skills on the trip. Muddiest Point assessments indicated that while a few concepts were still unclear for some students, the majority reported gains in understanding, particularly noting newfound insights into the rock cycle.

When asked about their value, students reported that both ‘frontloading’ and post-trip ‘summarizing’ activities to be useful, but these weren’t the first topics to come to their minds when asked about moments of insight, or overall impressions. As repetition is the mother of learning, these were important components of the trip, but the part of the trip that really connected with students was the actual excursion, outside, interacting with nature and thinking about geologic processes and their signatures.

Based on previous semesters’ action research with geology field trips, I was expecting to hear that the student-centered exploration was the part this semester’s students most appreciated. However, I found that a suprising number specifically commented that they appreciated my familiarity with the site and my organization of the trip. For the introductory geology student, the ideal field trip is apparently not entirely exploration based or 100% guided tour. It appears that both trip ‘flavors’ were appreciated. Students expressed appreciation for both student-centered exploration and instructor-led discussion, as well as short-term ‘focused exploration’ with a specific observation in mind. The observations and their implications were teased out in a dynamic way, and there is no one technique that is ideal for teaching everything. Concepts learned were solidified and connected during end-of-trip summarizing activities when time permitted. Interviews and survey questions also indicated an enhanced perspective on our area’s rich history. Whether they enjoyed the trip just because it was fun to get out of the classroom for a day, or whether it was a genuine moment of realization and profound insight, the students unequivocally indicated that they enjoyed spending the day looking at the world through geology-colored glasses.

Engaging in this action research project has been of significant importance to my development as an instructor. By regularly reflecting on the effects of my teaching, I have come to a new sense of perspective on the role of field trips in geologic learning, among other issues. I've also had incidences of finding myself practicing active reflecting on tests, student engagement, and 'office politics' with my colleagues. Additionally, the distinction between assessment and evaluation was obscure to me until I began delving into action research. Now, I have a fuller sense of what good assessment looks like and how important it is. I have incorporated assessments more deliberately into my teaching strategy. Overall, the action research process has developed into a new tool for use in my work; a tool like a Swiss Army knife, with multiple functions that can be fitted to new and varied circumstances.

My engagement with the question of field trips' role in learning geology will not conclude with this project. The affirmation I have gained by systematically investigating geology field trips will keep me doing them for a long time. I can predict some potential further avenues of research. For instance, I am curious about whether the medium of my evaluation has a particular effect on the students' learning. Right now, I have the students write a paper about the trip, synthesizing evidence and observation into interpretation and an overall story. But writing an essay takes other skills besides pure geology. Essays are compositionally complex, and require skills beyond those I teach in my class. Would my students be better off if I were to use a different form of evaluation?

Another idea that has repeatedly arisen in my mind and in the minds of student interviewees has been the notion of multiple field trips in a semester. The idea is to use an initial field trip early on in the semester as a motivational tool; something to inspire the students to learn. Later in the semester, a different trip to a different location would actually be used as learning experience and/or evaluation exercise. In the Spring 2009 semester, several students attended several students attended multiple field trips with me. For instance, one student attended my Billy Goat Trail field trip for Physical Geology as well as a recreational hike to Old Rag Mountain with the GeoClub and a 1-credit Field Studies in Geology class trip to Massanutten Mountain. In post-trip interviews, he told me that the multiple trips gave him an enhanced perspective. “I learned a lot about scales of deformation and metamorphism,” he said. “How large regional metamorphism can be; how small it can be; how large an anticline can be or how small. This gave me a sense of scale that pictures can hint at but seeing it [in person] makes a difference. I think that’s an important concept in geology: different scales.”

Perhaps the second field trip could even be to the same location as the first field trip. How would students’ perspectives change on visiting the same place twice, once as an eye-opener, and then again with a semester of introductory geology under their belt? We have all heard that repetition is the mother of learning, but does that apply to the experience of going on a field trip, too? It is safe to say that I will be in the field of field trip research for some time to come.

References Cited

Ambers, Rebecca K.R. (2005). “The value of reservoir-bottom field trips for undergraduate geology courses.” *Journal of Geoscience Education*, v.53, n.5, p.508-512.

Anderson, V. (1980). *Field tripping.* Toronto: Ontario Institute for Studies in Education, Informal Series n.21.

Angelo, Thomas A., and Cross, K. Patricia. (1993). *Classroom Assessment Techniques*. San Francisco, CA: Jossey-Bass.

Benson, Rod (2001). “Use of a virtual field trip to enhance geology education among freshmen Earth Science students.” Action research capstone paper, Montana State University - Bozeman: July 2001.

Buddington, Andrew M. (2006). “A field-based, writing intensive undergraduate course on Pacific Northwest geology.” *Journal of Geoscience Education*, v.54, n.5, p.584-587.

Darby, Dennis A., and Lloyd H. Burckle (1975). “Student-initiated field studies,” *Journal of Geological Education*, v.23, p.25-26.

Delaney, Arthur A. (1967). “An experimental investigation of the effectiveness of the teacher's introduction in implementing a science field trip.” *Science Education*, v.51, n.5, p.474-481.

Elkins, Joe T., Nichole M.L. Elkins, and Sarah N.J. Hemmings (2008). “Geojourney: a field-based, interdisciplinary approach to teaching geology, Native American cultures, and environmental studies.” *Journal of College Science Teaching*, v.37, n.3, p.18-28.

Elkins, Joe T., and Nichole M.L. Elkins (2007). "Teaching geology in the field: significant geoscience concept gains in entirely field-based introductory geology courses." *Journal of Geoscience Education*, v.55, n.2, p.126-132.

Elkins, Joe T., and Nichole M.L. Elkins (2006). "Improving student learning during travel time on field trips using an innovative, portable audio/video system." *Journal of Geoscience Education*, v.54, n.2, p.147-152.

Eves, Robert L., Larry E. Davis, D. Gordon Brown, and William L. Lamberts (2007). "Integration of field studies and undergraduate research into an interdisciplinary course." *Journal of College Science Teaching,* v.36, n.6, p.22-27.

Falk, John H., and Lynn D. Dierking (1997). "School Field Trips: Assessing Their Long Term Impact." *Curator*, v.40, n.3, p.211-218.

Falk, John H., and John D. Balling (1979). *Setting a neglected variable in science education: investigations into outdoor field trips*. Final report. National Science Foundation, Washington, DC.

Fido, H.S.A., and C.G. Gayford (1982). "Field work and the biology teacher: a survey in secondary schools in England and Wales." *Journal of Biological Education*, v.16, n.1, p.27-34.

Folkomer, Timothy H. (1981). "Comparison of three methods of teaching geology in junior high school." *Journal of Geological Education*, v.29, p.74-75.

Greenberg, Jeffrey K. “Indoor field study for structural geology course.” *Journal of Geoscience Education*, v.50, n.5, p.575-582.

Hoffman, James I., and C.W. Fetter, Jr. (1975). “Field trip modules as complete substitutes for weekly introductory laboratories.” *Journal of Geological Education*, v.23, p.18-19.

Huntoon, Jacqueline E., Gregg J.S. Bluth, and William A. Kennedy (2001). “Measuring the effects of a research-based field experience on undergraduates and K-12 teachers.” *Journal of Geoscience Education*, v.49, n.3, p.235-248.

Karabinos, Paul, Heather M. Stoll, and William T. Fox (1992). “Attracting students to science through field exercises in geology.” *Journal of Geological Education*, v.40, p.302-305.

Kean, William F., and Larry G. Enochs (2001). “Urban field geology for K-8 teachers.” *Journal of Geoscience Education*, v.49, n.4, p.358-363.

Kern, Ernest L., and John R. Carpenter (1986). “Effect of field activities on student learning.” *Journal of Geological Education*, v.34, p.180.

Knapp, Doug (2000). “Memorable experiences of a science field trip.” *School Science and Mathematics*, v.100, n.2, p.65-72.

Knapp, Elizabeth P., Lisa Greer, Christopher D. Connors, and David J. Harbor (2006). “Field-based instruction as part of a balanced geoscience curriculum at Washington and Lee University.” *Journal of Geoscience Education*, v.54, n.2, p.103-108.

Lathrop, Alison S., and Ballard E. Ebbett (2006). “An inexpensive, concentrated field experience across the Cordillera.” *Journal of Geoscience Education*, v.54, n.2, p.165-171.

Libarkin, Julie C., and Steven W. Anderson (2005). "Assessment of Learning in Entry-Level Geoscience Courses: Results from the Geoscience Concept Inventory**,"** *Journal of Geoscience Education*, v.53, n.4, p.394-401.

Locke, William W. (1989). "A nontraditional geology field trip." *Journal of Geological Education*, v.37, p.107-109.

MacDonald, Heather R., Cathryn A. Manduca, David W. Mogk, and Barbara J. Tewksbury (2005). "Teaching methods in undergraduate earth science courses: Results of the 2004 *On The Cutting Edge* survey of U.S. faculty." *Journal of Geoscience Education*, v.53, n.3, p.237-252.

Manner, Barbara M. (1995). "Field studies benefit students and teachers." *Journal of Geological Education*, v.43, p.128-131.

Matty, David J. (2006). "Campus landscaping by constructing mock geologic outcrops." *Journal of Geoscience Education*, v.54, n.4, p. 445-451.

McClennen, Charles E., and Audrey W. Meyer (2002). "Transferable elements of the education program SEA Semester." *Journal of Geoscience Education*, v.50, n.3, p.266-270.

Mulligan, Michael M. (2004). "Can field exercises lead students toward making connections between principles of geology and biological processes?" Action research capstone paper, Montana State University - Bozeman: July 2004.

National Association of Geoscience Teachers (2008). "Teaching in the field." Webpage. http://www.nagt.org/nagt/field/index.html, accessed on March 1, 2008.

National Research Council (1999). *How People Learn*, Washington DC: National Academy Press.

Nazier, G. L. (1993). “Science and engineering professors: Why did they choose science as a career?” *School Science and Mathematics*, v.31, n.10, p.321-324.

Neff, Thomas R. (1977). “The use of field trip courses to strengthen undergraduate geology programs.” *Journal of Geological Education*, v.25, p.26-28.

Newmann, F.M. and G.G. Wehlage (1993). “Five standards of authentic instruction,” E*ducational Leadership*, v.50, n.7, p.8-12.

Noel, James A., and Philip G. Malone (1971). “Recording a field trip.” *Journal of Geological Education*, v.19, n.5, p.221-222.

Orion, Nir, and Avi Hofstein (1991). “Factors which influence learning during a scientific field trip in a natural environment.” Paper presented at the National Association for Research in Science Teaching, Lake Geneva, Wisconsin, April 7-10, 1991. 14 p.

Orion, Nir (1989). “Development of a high-school geology course based on field trips.” *Journal of Geological Education*, v.37, p.13-17.

Osbourne, Mary Jo (1988). “An 8000-mile, 38-day field trip for high-school students.” *Journal of Geological Education*, v.36, p.177-181.

Peavy, Kenny (2006). “Is just being outdoors enough? A comparison of a one week outdoor adventure program (Malaysia Week) and a one semester natural history course (The WILD Malaysia semester course) on middle school student attitudes toward the environment." Action research capstone paper, Montana State University - Bozeman: June 2006.

Pederson, Darryll T. (1978). "Effectiveness of field trips in teaching groundwater concepts." *Journal of Geological Education,* v.27, p.11-12.

Plymate, Thomas G., Kevin R. Evans, Melida Gutierrez, and Erwin J. Mantei (2005). "Alumni of geology B.S. program express strong support for field geology and related field and laboratory experiences." *Journal of Geoscience Education,* v.53, n.2, p.215-216.

Reynolds, Robert W. (2004). "On the practical aspects of incorporating field-based projects into introductory oceanography." *Journal of Geoscience Education,* v.52, n.3, p.218-223.

Riecker, Robert E., and Priscilla P. Dudley (1971). "Encounter with the many-colored stones." *Journal of Geological Education,* v.19, n.1, p.41-43.

Rodbell, Donald T., and Paul T. Grenillion (2005). "A winter-based course on limnology and paleolimnology." *Journal of Geoscience Education*, v.53, n.5, p.494-500.

Rudman, C. L. (1994). "A Review of the Use and Implementation of Science Field Trips," *School Science and Mathematics,* v.94, n.3, p.138-141.

Spencer, Edgar W. (1990). "Introductory geology with a field emphasis." *Journal of Geological Education,* v.38, p.246-248.

Stanesco, John D. (1991). "The personal journal as a learning and evaluation tool in geology field-trip classes." *Journal of Geological Education,* v.39, p.204-205.

Thomson, Jennifer A., John P. Buchanan, and Suzanne Schwab (2006). "An integrative summer field course in geology and biology for K-12 instructors and college and continuing education students at Eastern Washington University and beyond." *Journal of Geoscience Education*, v.54, n.5, p.588-595.

Zen, E-an (2001). "What is deep time and why should anyone care?" *Journal of Geoscience Education*, v.49, n.1, p.5-9.

Appendix

Appendix A. Online survey questions

Pre-Trip Survey:

1) Choose a name for taking this survey. You will use this SAME name for the follow-up survey in a couple of weeks. This could be your real name, or it could be a fake name that you invent. So long as you're consistent, I don't care. This survey doesn't effect your grade in any way, so it doesn't matter what name you choose. Write your "survey name" in the box below:
2) How would you evaluate your skill level at the following? (Choose from: Awful; Worse than most people, better than some; About Average; Better than most people, worse than some; or Excellent.)
    - Mineral identification
    - Rock identification
    - Igneous rock interpretation
    - Sedimentary rock interpretation
    - Metamorphic rock interpretation
    - Order of geologic events (relative dating)
    - Understanding plate tectonics in general
    - Evaluating plate tectonic scenarios from local rocks
    - Formulating and testing geologic hypotheses
    - Understanding landscape change
    - Understanding river processes
    - Ability to write

- Physical fitness and hiking ability
- Comfort level outdoors

3) Which of the following best describes how you learn geology the best?
    - By reading the textbook
    - By watching television programs
    - By listening to lectures
    - By performing lab exercises
    - By going on field trips
    - By surfing the internet
    - Other (please specify below)

Post-Trip Survey:

1) Enter your name for taking this survey. This is the SAME name you used in the pre-trip survey a couple of weeks ago. (It may have been your real name, or it may have been a fake name that you invented.) Please be consistent so that I can compare "before" and "after" results. Reminder: This survey doesn't affect your grade in any way.
2) How would you evaluate your skill level at the following? (Choose from: Awful; Worse than most people, better than some; About Average; Better than most people, worse than some; or Excellent.)
    - Mineral identification
    - Rock identification
    - Igneous rock interpretation
    - Sedimentary rock interpretation
    - Metamorphic rock interpretation

- Order of geologic events (relative dating)
- Understanding plate tectonics in general
- Evaluating plate tectonic scenarios from local rocks
- Formulating and testing geologic hypotheses
- Understanding landscape change
- Understanding river processes
- Ability to write
- Physical fitness and hiking ability
- Comfort level outdoors

3) Which of the following best describes how you learn geology the best?
   - By reading the textbook
   - By watching television programs
   - By listening to lectures
   - By performing lab exercises
   - By going on field trips
   - By surfing the internet
   - Other (please specify below)
4) What was your favorite moment on the field trip?
5) What changes would you suggest to improve this field trip?
6) In your opinion, considering all the pros and cons, was our field trip a worthwhile experience for learning geology? Why or why not?
7) What did you think of the peer review process? Was it effective or not? What changes, if any, would you suggest? (Spring 2009 only)

8) Is there anything else you would like me to know?

Appendix B. Formal interview questions

How was the field trip for you? (open-ended "opener" question)

What were some positive aspects of the field trip?

What worked well on the trip insofar as encouraging geologic learning is concerned?

Describe a moment of insight that you had on the trip (if any).

What were some things that I did as field trip leader that you thought didn't work so well?

Describe the usefulness of the visual aides I brought along.

What should I do differently in running the trip again in future semesters?

Which is a better way to run a field trip: as a guided tour, or as student-centered exploration and discovery?

Of what use was the course website?

Of what use was the assignment of writing a paper after the trip?

Is there anything else you would like for me to know?

Appendix C. Rubric for scoring field trip papers

Organization:

10 points Paper is well organized, with a clear progression of ideas and content.
5 points Paper is moderately organized, with some lapses in coherent progression of ideas or lapses in logic.
2 points Paper is poorly organized, with no coherent progression of ideas or content, and numerous lapses in logic.

10 points Paper is organized geo-chronologically: that is, in the order things happened in geologic history (not in the order we observed them on the trip).
5 points Paper is organized trip-chronologically: that is, in the order evidence was observed on the trip (not in the order they happened in geologic history).
2 points Paper is displays no chronological organization whatsoever, but instead skips around chaotically between topics.

Writing, grammar, spelling, and formatting:

10 points Paper is well written, with a mastery of the English language, spelling, & sentence structure.
5 points Paper is moderately written, with some grammatical and spelling errors.
2 points Paper is poorly written, with an unacceptable number of grammatical and spelling errors.

10 points Paper is focused and relevant, with a minimal amount of extra words.
5 points Paper is mostly focused and mostly relevant, but displays some "fluff" ("It was so interesting," "I've never been outside before," etc.)
2 points Paper contains a large amount of "fluff" ("I really enjoyed this trip," etc.) and a minimal amount of real content.

3 points Separate paragraphs correspond to separate topics being discussed.
0 points Paper uses only one big long paragraph, or breaks between paragraphs do not correspond with changes in topics being discussed.

2 points The paper is properly formatted (Times New Roman font, double-spaced, with 1¼" margins).
0 points The paper is formatted in some way other than the assigned format of Times New Roman font, double-spaced, with 1¼" margins.
-2 points Paper includes a title page, which was specifically forbidden. (negative points for wasting paper)

3 points Citations are used for outside information, and are consistently formatted (either MLA or APA).
2 point Paper cites sources, but inconsistently or incompletely.
0 points Paper does not cite its sources.

2 points Illustrations are clear, labeled correctly, and relevant to the topics being discussed.
1 point Illustrations are not used.
0 points Illustrations are unclear, labeled incorrectly, and/or irrelevant to the topics being discussed.

Geological content:

10 points Student has clearly distinguished between geological observations and interpretations.
5 points Student has mostly distinguished between geological observations and interpretations, but has mixed them up in a few places.
2 points Student has not distinguished at all between geological observations and interpretations.

10 points Student has clearly stated all geologic evidence observed on the trip.
5 points Student has stated most geologic evidence observed on the trip, but has left out some key observations.
2 points Student has stated only a minimal amount of the geologic evidence observed on the trip.

10 points Student has gotten all of their geological facts right.
5 points Student has gotten most geological facts right, but made a few minor errors.
2 points Student has made numerous factual errors of geology, but got a few things right.

10 points Paper describes the correct chronology (order in time) of geologic events.
5 points Paper describes a mostly correct chronology (order in time) of geologic events.
2 points Paper describes an utterly incorrect chronology (order in time) of geologic events.

10 points All trip stops (field locations) are mentioned.
5 points Most trips stops are mentioned, but some are missing.
2 points A minimal number of trip stops are mentioned, but most are missing.

Appendix D. “Muddiest Point” classroom assessment technique

What was one thing that you understand better as a result of today’s field trip?

What is one thing you don’t understand about the material covered on today’s field trip?