Virtual Field Trips for Introductory Geoscience Classes

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Abstract

Field trips are a core component of geoscience education. Multiple factors have made taking field trips difficult, and many schools no longer take introductory-level classes on field trips. The Virtual Field Trip of California Geomorphology was developed as a solution to provide an alternative to real field trips. The Virtual Field Trip of California Geomorphology brings some of the most dynamic elements of technology, including Google Earth, Google Maps, and annotated photographs from field sites around the state to the student's computer or smart phone. The field trip is based on a series of real field trips to the eastern Sierra, the Carrizo Plain, and the central Coast Ranges in California. The Virtual Field Trip is modular, and it employs detailed, module-level learning outcomes with guided inquiry worksheets. Applications of technology, learning design, and cognitive and affective learning outcomes are discussed.

Introduction

Field trips have a long tradition as a core component of geoscience education. Upper-division level field trips that last days to weeks and involve problem-oriented learning are an essential component of the geosciences major (Whitmeyer, Mogk, and Pyle 2009). In introductory geoscience classes, field trips reinforce classroom concepts, instill an appreciation for the natural world, and recruit majors.

Taking classes on field trips has become increasingly difficult. It is challenging for an instructor to organize a field trip due to limited budgets, large classes, and an institutional wariness of potential legal liabilities. In addition, the field is not always accessible to students with disabilities, and students' work, sports, and class schedules often conflict with field trips. These concerns have caused many geography departments to eliminate field trips for introductory-level classes.

Virtual field trips provide an alternative to "real" field trips. Virtual field trips can be made fully accessible to persons with disabilities, and they are available anytime, from almost anywhere. The Virtual Field Trip of California Geomorphology was developed to provide a field-trip experience for students in introductory physical geography classes.

The Virtual Field Trip of California Geomorphology provides an observation-based, problem-solving field experience. The project is based on two five-day field trips (one to the eastern Sierra and a second to the Carrizo Plain and central Coast Ranges) in the fall of 2011, led by Kurt Cuffey, professor of geography at UC Berkeley. The Virtual Field Trip is licensed under a Creative Commons Attribution-Noncommercial-Share Alike 3.0 Unported License and is posted on the Web at www.foothill.edu/fac/klenkeit/virtual/

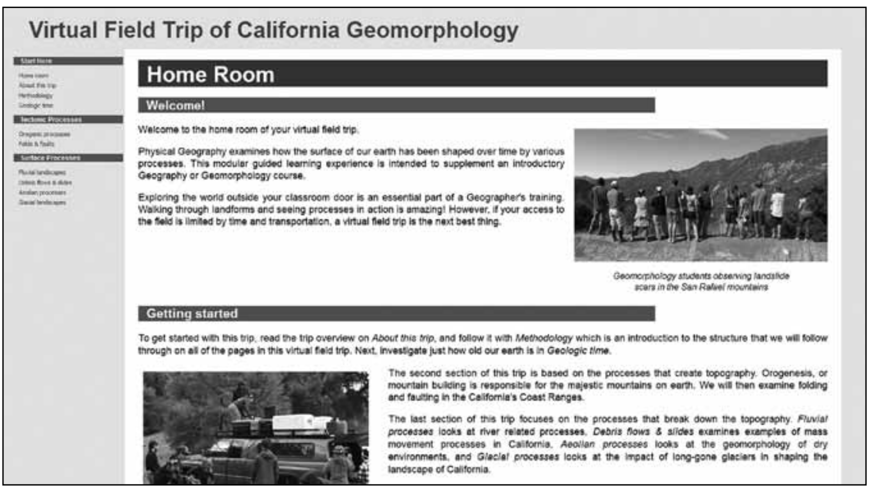

Figure 1.—Virtual Field Trip Home page.

The Virtual Field Trip is organized thematically around tectonic and surface processes typically covered in an introductory-level physical geography class. It visits twenty-five field sites around California and uses guided inquiry to meet specific learning outcomes. The Virtual Field Trip integrates annotated photographs, models, and interactive Google Maps and Google Earth interfaces with Keyhole Markup Language (KML) overlays to provide students with an immersive, guided field experience.

Background

Pedagogy on field trips varies greatly (Kent et al. 1997). Field trip styles range from the observation-based "Cooks tour" to problem-oriented, project-based field trips. Observation-based field trips cover a greater breadth of topics, while project-based participatory field trips go into great depth on a few narrow subjects.

Observation-based field trips provide a broad overview of an unfamiliar landscape. Learning in this type of field trip is more effective when conducted in an interactive tutorial style with observation and discussion of landscape features (Couch 1985, Gold 1991). However, students generally miss key features, and when prompted will more readily reproduce the instructor's observations rather than constructing their own theories (Haigh and Gold 1993).

The Socratic method of teaching with observation-based field trips is effective, but is dependent on a low instructor-to-student ratio, and it quickly loses effectiveness in large group settings. Observation-based field trips can be made most effective when student learning is focused with carefully crafted worksheets. These are filled out based on student observations over the course of the trip (Keene 1982, Slater 1993, Jenkins and Daniel 1993).

A second mode of pedagogy in the field is participatory field trips. Participatory field trips encourage deep learning through "learning by doing" (Wiley and Humphries 1985, Wheater 1989). There are many logistic considerations to engaging in participatory field trips with large groups (Kent et al. 1997). In order to be most effective, participatory field trips require significant instructor supervision. Participatory field trips also require more time in the field and tend to go into great depth on a few narrow subjects. At the introductory level, most field trips are observation-based with the goal of reinforcing a broad range of concepts introduced in the classroom.

Computer-aided learning in geoscience classes has been explored for over three decades. Initially, computers were used as a tool to aid in the analysis of data. Shepherd (1985) suggested that computers should be used to teach geography concepts, an idea that has been explored by many authors since (Unwin 1991, Wentz 1999, Stumpf et al. 2008, DePaor and Whitmeyer 2009, Whitmeyer et al. 2009, Stokes et al. 2012, and Kolivras et al. 2012).

Geoscientists have been slow to embrace virtual field trips as an alternative to actual field trips (Stumpf et al. 2008). The immersive experience of the field is of cardinal importance to most geoscientists. Hiking through landscapes allows students to appreciate the scale, complexity, and frequency of geomorphic features. The fun, excitement, and camaraderie of the field are also a significant recruiting tool for majors. However, the need to make field trips accessible to persons with disabilities or schedule conflicts, and the need to make the field accessible to large classes, has prompted an interest in developing virtual field trips for introductory-level instruction (Spicer and Stratford 2001, Stumpf et al. 2008, Stokes et al. 2012, and Kolivras et al. 2012).

Wentz et al. (1999) found that using computer tools such as visualization based CD ROMs and a simplified Geographic Information System in conjunction with the regular course materials in an introductory Geomorphology class enhanced student learning and engagement compared with offering the course without the technological enhancements. Spicer and Stratford (2001) used virtual field work in an undergraduate biology class and found that it reinforced the thought processes underpinning field work, but the overall experience of "real" field work was far superior to virtual field work and they concluded that the virtual experience should not replace a real field experience.

These early forays into virtual field trips all echo the criticism that virtual field work is not the same as 'being there'. Indeed, early computer graphics provided little more than simple choropleth maps on the computer screen. However, advances in computer graphics technology have greatly improved the visual component of virtual field work and create a significantly improved immersive experience compared to computer graphics a decade ago.

The immersive sensory experience associated with field trips reinforces learning because it stimulates the affective domain (Stokes and Boyle 2009). Sensory input from sights, smells, and sounds prompts responses in the affective domain that interact with the cognitive and psychomotor domains to produce deep learning (Eiss and Harbeck 1969). The early virtual field trips were perhaps less successful at producing the same excitement for the field as actually being there because the limitations of computer graphics, computer animation, digital photography, and Web technology limited the stimulation of the affective learning domain.

Learning is composed of three interactive processes: cognitive, affective, and psychomotor (Eiss and Harbeck 1969). The cognitive domain (knowledge, understanding, and conceptualization) is what is traditionally emphasized in the classroom. The cognitive domain and the psychomotor domain (practical skills such as operating field instruments) are commonly assessed in field trips. The affective domain includes representations of value and includes emotions, attitudes, and feelings, which can reflect positive or negative value or feelings (Clore et al. 2001). Affective outcomes influence cognitive outcomes (Ashby et al. 1999, Isen 2000); however, affective outcomes are rarely assessed (Stokes and Boyle 2009).

While early virtual field trips produced mixed success in equaling the cognitive learning outcomes of real field work, more-recent virtual field trips have had better results (Stumpf et al. 2008, Kolivras et al. 2012, and Stokes et al. 2012). In each case, a post-test assessment found no difference in the basic knowledge or cognitive learning outcomes of students who had taken the virtual field trip compared to those who had taken the real field trip. However, they found that the students who had taken the real field trip had a greater qualitative appreciation and positive attitude about the natural environment, or more-successful affective learning outcomes. The authors concluded that virtual field trips were a cost-effective alternative to real field trips and provided access to the field for students who otherwise could not participate in a field trip at an introductory level.

Virtual Field Trip of California Geomorphology

The Virtual Field Trip was created as part of a sabbatical leave project that Professor Lenkeit Meezan undertook in the fall of 2011. Professor Lenkeit Meezan teaches geography at Foothill College, a California community college in the San Francisco Bay Area. Foothill College is an urban community college with approximately 16,500 full-time-equivalent students. The Geography Department, with an annual enrollment of 1,050 students, offers an associate's degree as well as a transfer degree to the California State University system. The Geography Department has one full-time and six adjunct instructors. Physical Geography satisfies the California State University (CSU) and University of California (UC) lab science general education transfer requirement, and is the most popular class in the department, with around seven hundred students enrolled annually.

Foothill geography classes lack an actual field-trip component for three reasons. First, the college provides no financial support for field trips. Second, concerns about liability have made field-trip paperwork for students and instructors extremely onerous. Finally, because a community college is a nonresidential campus and many students are "nontraditional," the logistics of organizing an all-day field trip are very challenging.

The Virtual Field Trip of California Geomorphology is widely applicable to any introductory physical geography or geomorphology class. The Virtual Field Trip allows students to visit twenty-five sites of geographic interest around California. Its modular nature means that it can be completed over several days in classroom laboratory time, or as a self-guided component external to scheduled class time. The field trip has worksheets that are linked to each module and guide the student's observation and inquiry.

All of the pages of the Virtual Field Trip of California Geomorphology have a clean, easily navigable design. Key terms are defined in boxes on each screen. Users navigate through the Virtual Field Trip using a navigation bar on the left side of the screen. Breadcrumbs-style navigation guides users through each module. The page meets ADA accessibility standards for screen readers and is built with XHTML and linked CSS style sheets.

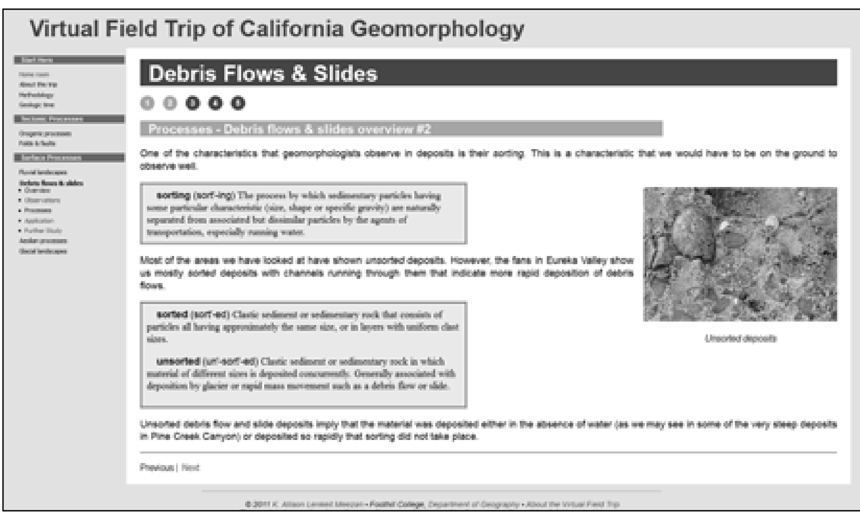

Figure 2.—Master navigation bar for the Virtual Field Trip is on the left side of the screen. Breadcrumbs (numbered) navigation for the Debris Flows & Slides module on the top.

Each section contains a series of self-contained modules. Each module (such as *Fluvial Processes*) is defined by a unified color scheme which provides the user with a visual cue to identify and define the process.

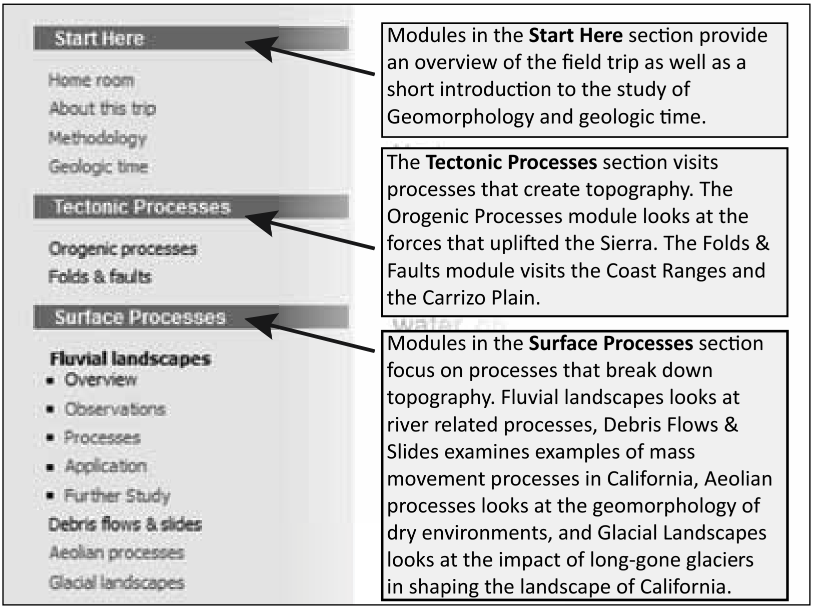

Figure 3.—Close up of the navigation bar with the Fluvial Processes module expanded to quick link to each module section.

Each module follows the same structure:

I. **Overview**—Provides a short summary of the process or landscape being visited.

II. **Observations**—Three to six sites are visited and the student is prompted to make observations about the site, based on interactive Google Maps (map, terrain, or satellite), Google Earth, and annotated photographs.

III. **Processes**—Sites are revisited, this time with additional discussion and description of the processes that underlie the formation of the features. Students are prompted to make additional observations.

IV. **Application**—Students visit a new site and are asked to apply the knowledge they have gained to the new landscape.

V. **Further study**—Key academic papers relevant to the features visited are summarized.

The Virtual Field Trip of California Geomorphology was integrated into the laboratory section of two Introductory Physical Geography classes at Foothill College with a total of sixty-eight students enrolled. Modules of the field trip were required throughout the quarter, timed to coincide with the different subjects being covered in class. Student response to the Virtual Field Trip was overall positive, based on anonymous evaluations submitted after completing the field trip and informal conversations with students. Most students had little trouble navigating the field-trip interface and using the Google Maps and Google Earth interfaces embedded in the Web pages. However, the instructor observed that unless the lab worksheet had specific questions prompting students to interact with the landscape visualization interfaces, many students would make only a cursory exploration of the interactive landscape visualization.

Learning Outcomes

There is a void in published literature on learning outcomes for field trips in introductory-level courses. On the other hand, numerous papers have been written about learning outcomes and teaching techniques for upper-division field trips in the earth sciences. The Geological Society of America has published a special paper on Field Geology Education (no. 461) that focuses on upper-division level "field camps." However, students in upper-division field classes have already successfully achieved the basic learning outcomes expected from introductory coursework. Because of this lack of precedent in the academic literature for introductory-level courses, the first author on this paper has built the learning outcomes for this project based on her own experience and on informal discussions with other instructors of introductory-level geography courses.

In an introductory-level course, the objectives of field trips are threefold. First, students hone observation skills and learn to visually identify features in the field. Second, students appraise the integrated elements that contribute to the formation and structure of a landscape. Finally, they construct hypotheses for how landscapes change over time. In other words, field trips have both very low-order (knowledge and comprehension) and very high-order (synthesis) learning outcomes. The measured learning outcomes are almost entirely cognitive, for field trips at the introductory-course level. In upper-division field trips, assessed learning outcomes tend to be higher order, and more of an emphasis is placed on psychomotor outcomes such as operating instruments.

Affective learning outcomes are rarely assessed at any level, in large part because they are usually qualitative in nature and therefore more difficult to assess. While the affective learning domain is not generally assessed, the positive learning outcomes from this domain can increase the number of students who choose geography as a major, or simply stimulate greater interest in class material and contribute to positive cognitive outcomes.

The digital medium has some advantages and some disadvantages over the traditional field trip in achieving student learning outcomes. In addition to the advantages of increased accessibility for students with physical limitations or busy schedules, students taking a virtual field trip can visit the field sites in short doses, making it more likely that they will maintain focus. Students in a climate-controlled room are also more able to focus on learning objectives than students trying to make observations and draw conclusions in extremely hot, cold, windy, or rainy weather.

Virtual field trips are limited by current computer technology. Observations of the complexity and scale of elements are mostly lost in translation to the twelve-by-eighteen-inch computer monitor, and students who visit several thematic field sites in a laboratory period are less likely to make landscape-scale connections between geomorphic features. In addition, the same harsh environmental factors that can hinder learning in the field also help to build a sense of camaraderie among field-trip participants, which has been shown to enhance learning (Stokes and Boyle 2009). Field trips that include pleasant weather and beautiful scenery create a great deal of positive learning in the affective domain. This can lead to enhanced learning in the cognitive domain.

Advances in computer graphics and user-interface design have improved the user experience for students taking a virtual field trip. It is possible that in the near future, affective learning outcomes for virtual field trips will approach those for real field trips.

Table 1 describes the module-level learning outcomes for the Virtual Field Trip of California Geomorphology. About half of the learning outcomes are knowledge- and comprehension-based, with the remainder divided between application, analysis, and synthesis. The Virtual Field Trip is intended to supplement an introductory Physical Geography class. To achieve the field-trip learning outcomes, it

Table 1: Learning outcomes for the Virtual Field Trip of California Geomorphology.

Tectonic Processes

Orogenic Processes

Diagram relative ages of analogous rock units based on weathering

Relate features such as roof pendants to the volcanic and tectonic processes that formed them

Interpret the relationship between volcanic features and their regional tectonic setting

Identify erosion platform features

Describe the processes that formed erosion platforms

Folds and Faults

Identify evidence of fault movement

Calculate the rate of fault movement

Identify examples of tectonic deformation such as anticlines and synclines

Surface Processes

Fluvial Landscapes

Describe the stages of channel development

Compare areas that exhibit high drainage density with areas that exhibit low drainage density

Discuss the physical factors and climate that produce badlands

Identify evidence of a stream formed valley (as compared to a glacial valley)

Compare straight, meandering, and braided channels in terms of their channel form and patterns of erosion and deposition

Debris Flows and Slides

Identify *clast-supported* deposits and *matrix-supported* deposits

Identify *sorted* and *unsorted* deposits

Describe topographic evidence of landslide deposits

Examine the factors that contribute to a debris flow or slide

Assess the impacts of debris flow and landslide deposits on communities, and what people can do to mitigate these hazards

Aeolian Processes

Relate dune formation and movement to wind strength and direction

Describe how wind moves particles

Discuss how lag deposits are formed and why they are important

Glacial Landscapes

Identify evidence of a glacially formed valley (as opposed to a stream-cut valley)

Identify features including moraines, cirques, and arêtes

Identify glacial polish and glacial erratics

Describe how glaciers formed moraines, cirques, arêtes, polish, and erratics is assumed that students also attend the quarter-long introductory Physical Geography class and complete the associated readings.

The learning outcomes associated with the virtual field trip were assessed with post-tests only. Students were largely successful in achieving the knowledge-based outcomes in the field-trip modules, but many struggled with the analysis and evaluation elements.

For example, students were highly successful in identifying features such as landslide profiles, stream-cut versus glacial valleys, moraines, and stream types such as meandering versus braided. However, success levels dropped when students were given such tasks as "Discuss the physical factors and climate that produces badlands" or "Relate features such as roof pendants to the volcanic and tectonic processes that formed them."

The Virtual Field Trip of California Geomorphology attempts to stimulate the affective domain of learning by creating a visually unified and pleasing interface populated with many on-the-ground photographs of features. In addition, it includes many photographs of students participating in the fall 2011 field trip. Photographs that included the professor and students engaged in academic discourse, packing up camp, or simply goofing off during down time help to create the feeling of "being there," and are one of the elements that

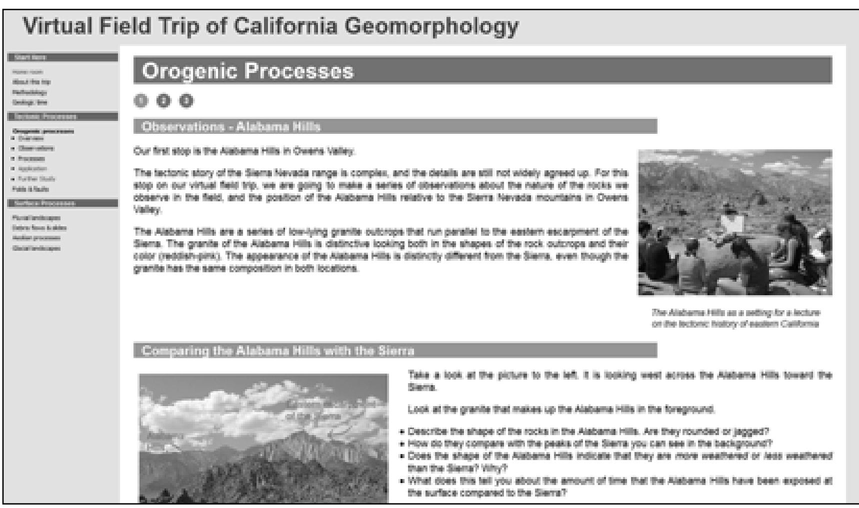

Figure 4.—On-the-ground photographs of students engaged in discussion with the professor in the field and annotated photographs received a positive response from students who took the Virtual Field Trip.

received the most positive responses from students who participated in the virtual field trip.

Technology, Learning Design, and the Virtual Field Trip

This project uniquely utilizes technology to access the virtual field experience in four ways. First, it engages the students with numerous on-the-ground photographs from real field trips with college students, creating the feel of a student looking at pictures of his or her own field trip. This is the aspect of the Virtual Field Trip project that has received the most enthusiastic feedback from students who have tested Version 1.0. The pictures of students listening to descriptions of the field site, taking notes, or packing up camp help to stimulate the affective element of the learning process and promote student engagement.

"It is a vicarious field trip!" a student commented during a virtual field trip session in the computer lab. Students have been conditioned by popular culture to have vicarious experiences. Reality TV shows allow people to vicariously travel the world and compete in feats of athletic stamina (*The Amazing Race*), starve and snipe at each other on a deserted island (*Survivor*), or date twenty beautiful people at one time (*The Bachelor)*. Showing pictures of students participating in all aspects of a real field trip allows the student in front of his or her computer screen to place him/herself in the picture, and get a small taste of the "being there" that is held up by many earth scientists as one of the key elements of field trips.

The second way in which this project uniquely utilizes technology to access the field is through the use of mashup maps embedded in the project Web pages. The Virtual Field Trip uses mashup geospatial mapping technology to allow students to view and interact with thematic maps and annotated overlays of the field sites. Mashup maps use raster and or vector map elements that are georeferenced and overlain on interactive Web mapping technology such as Google Maps or Open Street Map. In this case, Keyhole Markup Language (KML) files were generated using ArcGIS and then overlain on a Google Maps interface using simple Javascript. Version 1.0 of the Virtual Field Trip makes extensive use of the Google Maps or Google Earth embedded interface.

The Google Maps interface is especially useful because it allows the embedded map to display standard choropleth maps, satellite images, or shaded relief topographic maps. The Google Earth embedded map interface allows the student to "fly" through a three-dimensional landscape, view structural features from many different angles, and view features at both small and large scale. In this way, the virtual field trip is superior to actual field trips because students are not limited by roads or trails to get the perfect view of a geographic feature.

The Web pages in this project were built by the first author. They use basic XHTML with CSS. The embedded Google Earth and Google Maps interfaces were customized and embedded using the Google Maps interface under "embed or email map" and then "customize and preview embedded map." The KML overlays were generated using ArcGIS and the Google Maps editor tools.

The technology to build Web pages and customize and embed mash-up maps is accessible to mainstream computer users who have strong basic computer skills. This author has taken one class in XHTML and considers herself comfortable using and learning computer technology, but is not a computer programmer. The broader implication of the ease of access of this technology is that all earth science educators can, with some very basic training, create customized learning materials for their classes that can stimulate the affective element of student learning and engage tech-savvy students.

Geospatial technologies such as digital maps, three-dimensional topographic visualizations, pseudo-GIS overlays, and aerial photography/satellite imagery are fundamental to a modern geoscientist. While the technology underlying the geospatial technology interfaces in the Virtual Field Trip are complex, the level of technical knowledge required to build these pages is relatively low, and the level of technical expertise required for students to use them is lower still. The Virtual Field Trip allows students to gain experience using geospatial technologies within the context of their visits to field sites.

The third way that this project uniquely utilizes technology is through its thematic organization that takes advantage of hyper-linked pages to allow users to quickly access and navigate through many different geographic locations. "Real" field trips in California are, through necessity, usually organized geographically. However, by grouping the field sites thematically, students can more readily link material they have learned in textbooks or lectures to their observations in the field. In the course of one Virtual Field Trip module on fluvial processes, students visit six different sites across the state. These locations would take two days to cover on the ground, yet a student in the virtual field trip can examine and compare all six in the span of a few hours. Therefore, in the course of the lab field trip session, the student can focus on the one process and more readily make comparisons between the different field sites.

Finally, each module is supported with guided inquiry worksheets. As noted in the Background section of this paper, observational-type field trips are most effective with large groups when student attention is focused through carefully constructed worksheets. The worksheets used in the Virtual Field Trip can be printed out and filled in by hand, or completed using Acrobat PDF forms and simple computer sketching tools such as Paint. The questions on the worksheets ask students a range of comprehension-based questions as well as questions requiring some analytical thinking (Table 2).

Table 2: Sample worksheet questions.

Comprehension question	Analytical thinking question
Based on your observations of the meandering channel (Owens River), does deposition occur on the inside or outside of channel bends? List two pieces of evidence from your observations that support this.	Compare and contrast the factors contributing to flow rate, deposition, and erosion differences in straight and meandering channels.

Future Work

The Virtual Field Trip of California Geomorphology is a work in progress. Future work will focus on several elements. First, the guided learning worksheets need to be refined and more closely tied to the module learning outcomes. Along with this goal, the learning outcomes themselves should be revisited and refined. Additional compilations of learning outcomes from freshman-level earth science field trips are needed and the Virtual Field Trip learning outcomes need to be better aligned with these.

Second, additional photos should be added. Detailed photography needs to be added from each field site to provide better visualization of large-scale elements such as sorting of deposits. Also, based on the feedback that students taking the virtual field trip gave, more photos of students on actual field trips should be added.

Finally, additional sensory elements need to be added to better stimulate the affective component of learning that takes place in the field. The computer medium is limited to two of the five senses (sight and sound). However, descriptive language coupled with visual images can evoke smells, textures, and even tastes, creating a sense of place. A link to an audio file on every field site visited in the Observations section of each module would provide narration dubbed over background sounds recorded in the specific place (birds singing, insects buzzing, water rushing, wind).

Overall, the first draft of the Virtual Field Trip of California Geomorphology has made progress in the domain of virtual field trips. The rapid development of computer visualization technology has allowed for a significantly more "real" virtual field experience than was possible even five years ago. While the ideal continues to be field trips in introductory classes with student instructor ratios of less than ten to one, this is not possible in most colleges. As technology continues to advance, the option of taking introductory earth science students on virtual field trips should continue to be vigorously pursued.

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