Using Google Earth and Satellite Imagery to Foster Place-Based Teaching in an Introductory Physical Geology Course

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ABSTRACT

Students in an introductory physical geology course often have difficulty making connections between basic course topics and assembling key concepts (beyond textbook examples) to interpret how geologic processes shape the characteristics of the local and regional natural environment. As an approach to address these issues, we designed and implemented a semester-long place-based group project, which used satellite imagery and Google Earth as a means to improve both students' conceptual knowledge of geological concepts and their understanding of geological processes. The project provided the underlying framework for both lecture and laboratory activities and was designed to reiterate and strengthen the connections across topics. Findings suggest that when given the opportunity and tools to develop a sense of place in the local and regional environment, students improve their conceptual knowledge and ability to apply critical thinking skills. Consequently, student learning becomes more meaningful and relevant to their everyday experiences. © *2012 National Association of Geoscience Teachers*. [DOI: 10.5408/10-203.1]

Key words: critical thinking, Google Earth, place-based, satellite imagery, semester-long project, undergraduate education

INTRODUCTION

Instructional strategies and curricular materials purposefully designed to bridge the gap between students' classroom learning and everyday experiences can help make their learning relevant. In 2004, Etkina and Mestre reported that, especially for nonscience majors, the lack of connections between what students learn in the classroom and in their everyday experiences often contribute to their lack of motivation. Connecting learning to personal experience, either as a result of direct hands-on activities or indirectly through the description of familiar events, can be a powerful strategy for motivating and engaging students in meaningful learning (Schell and Black, 1997; Powers, 2004; Ardoin, 2006; McConnell et al., 2006).

Similar to what was observed by McConnell et al. (2006), we found in our teaching experiences that students often had difficulty applying their knowledge of concepts learned in class to interpret or ascribe geologic processes within the local, regional, or global landscape. Discussions resulting from our weekly strategizing meetings suggested two emerging themes. First, students seemed to compartmentalize geologic concepts and processes as isolated bits of information (Raia, 2005). As a result, they often lacked a clear understanding of how key concepts connected across topics or provided evidence to support "big picture ideas" such as plate tectonics. Second, students were typically more successful and confident in their ability to answer questions that relied on the memorization of facts than they were with questions that required critical thinking or reasoning from evidence to support their claims (Ball et al., 2001; Krathwohl, 2002; Mayer, 2002; McConnell et al., 2003).

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In an effort to address these concerns in ways that would help foster relevance to student learning, characteristics of place-based education were incorporated into laboratory activities, instructional strategies, and student assessment. Instrumental in our efforts was the design and implementation of a semester-long group project utilizing Google Earth and satellite imagery. The use of technology served as a valuable teaching tool and resource through which students could build a sense of place in the local and regional landscape of northern California. The term "sense of place" expresses the connections between people and places (Williams and Stewart, 1998; Lim and Calabrese Barton, 2006; Semken, 2008). A fundamental characteristic that establishes the foundation of place-based education, according to Woodhouse and Knapp (2000), "emerges from the particular attributes of a place. The content is specific to the geography, ecology, sociology, politics, and other dynamics of that place."

Northern California, and particularly the area around California State University, Chico, is well suited for utilizing place-based teaching strategies. The diverse terrain exposes excellent examples of nearly every topic covered in an introductory geology course, from volcanoes, mountains, rivers, and intricate groundwater systems to excellent exposures representing every aspect of the rock cycle. Although the San Andreas Fault transform margin and its recurring earthquakes define the state's modern tectonic fabric, northern California also houses excellent examples of convergent margin tectonics in both ancient (e.g., Sierra Nevada and the Coast Ranges) and modern (e.g., Cascades and Mt. Shasta) settings as well as divergent tectonics and related volcanism within the Basin and Range province.

Place-based education has typically been associated with outdoor education, service learning, and environmental education programs (Kawagley and Barnhardt, 1999; Cajete, 2000). However, studies by Semken and Freeman (2007), Riggs (2004), and Semken et al. (2009) have also added to the recognition and merit of place-based education and the attributes of geoscience place-based teaching in higher education. The overall aim of this study was to evaluate a semester-long place-based group project that incorporated satellite imagery and Google Earth as a viable pedagogical tool and curriculum resource to improve the students' content knowledge in an introductory physical geology course. We make the argument that if students have the opportunity to develop a sense of place in the local and regional area of northern California, then they would become more engaged and interested in learning about geology in general because of its relevance to their everyday experiences. The following objectives therefore framed the focus of this study:

- To increase conceptual knowledge of fundamental geoscience concepts
- To create connections between geoscience concepts
- To apply classroom content to geological features and applications in the local and regional landscape of northern California

This paper reports on the design and implementation of a semester-long group project using satellite imagery and Google Earth in an introductory physical geology course taught by the Department of Geological and Environmental Science at California State University, Chico. The catalyst for this project stemmed from the department's recent efforts to revise course curriculum and promote pedagogical strategies that engage the students in active learning, especially in traditionally taught laboratory settings. In response to this call, we decided to replace and modify existing course lectures and laboratories, making an effort to better integrate the two learning environments using attributes of place-based teaching as an approach to inform instructional strategies and curriculum design.

BACKGROUND

California State University, Chico is located in northern California, 170 mi north of San Francisco at the north end of the Sacramento Valley and the western edge of the Sierra Nevada foothills. The university has an average enrollment of slightly over 15,000 students. The average age of undergraduate students is 23, with 95% of the total student population coming from California. Student gender is 52% female and 48% male. Student gender is 52.66% female and 47.34% male. Student ethnicity is composed of 66.48% White, non-Latino, 12.40% Hispanic-Latino, 6.29% Asian American, 2.28% African American, 1.00% American Indian or Alaskan Native, 0.51% Native Hawaiian or other Pacific Islander, and the remaining 11.06% of unknown ethnicity or not reported.

In the fall semester of 2008, the authors of this paper taught different sections of the same introductory physical geology course. The course structure consisted of a weekly 1-h lecture and a weekly 3-h laboratory. Throughout the semester, we observed each other's classes to document the student discourse, strengths and weaknesses of the laboratory activities, and students' level of cognitive engagement during individual and group activities. Weekly meetings provided dedicated time to review classroom observations and reflect on student learning. The outcomes of these meetings served as a springboard for future iterations of the course design, pedagogy, and assessment strategies based on the needs of the students.

In this paper, we will report on three successive semesters of the course and distinguish between them as follows:

- Spring 2008 (baseline). At this point, the course did not incorporate any components of place-based teaching and assessment strategies.
- Fall 2008 (pilot study). The course design began to incorporate place-based teaching and assessment strategies and introduced a semester-long group activity using satellite imagery and a PowerPoint digital poster.
- Spring 2009 (complete redesign). The course design was driven by place-based teaching, and assessment strategies. Google Earth and satellite imagery were integrated into the lectures and laboratories and played an integral role in the development of the students' semester-long place-based group project.

PEDAGOGICAL TOOLS

Why Satellite Imagery and Google Earth?

Organizing geological concepts locally allows students to link new ideas to a place that is known from prior experiences. The advantage of using satellite imagery is that it is possible to screen or filter out superficial data (e.g., roads and cities) and to highlight only the features that are relevant to the concept (e.g., river paths, three-dimensional [3-D] topography, and shapes of valleys). Students can then make relevant observations and discuss, incorporating their own experiences, how these features were created. The ease of changing the scale allows the local scale (rivers and valleys) to be tied to a more regional scale (mountains and major relief changes), and eventually to a global scale (plate tectonic boundaries and plate types; Fig. 1).

For example, the concept of how base-level changes affect landscapes is a difficult one to visualize; it is also difficult for students to make the connection between processes affecting the local–regional–global scales. However, students are much more familiar and comfortable with local scales than they are with regional (mountain building) or global scales (plate tectonic movement). It is easier to recall a prior visit to a river or a mountain valley than it is to visualize how recent tectonic uplift of a mountain caused the river to incise a valley or how glaciers carved and modified its shape. Fortunately most students in northern California have visited a river and glacial valley in the Sierra Nevada (e.g., Yosemite or any river valley in the western Sierra). If technology can be used to figuratively "transport" students back to that place, they can then be asked to make more meaningful observations of what they saw at the local scale.

The use of Google Earth to demonstrate geologic principles is becoming more and more popular in geology courses (Greene and Shapiro, 2008). The free software is user-friendly, enabling quick viewing of geologic features at a variety of scales. Google Earth gives students: (1) hands-on, visually oriented tools to explore areas at a variety of scales and 3-D perspectives, (2) opportunities to quantify the aerial extent and shape of common geologic features, (3) the tools to allow students to overlay and make transparent any type of map or image on Google Earth images to better

FIGURE 1: Satellite image of northern California. The places represented by polygons and their associated letters correspond to the topic-specific questions listed in Appendix A.

interpret geologic phenomena, and (4) confidence to explore and interpret geologic features from places that are less familiar to the students from around the world. From the first week of the semester, students are exposed to Google Earth through "live" classroom demonstrations, in-class exercises, and hands-on exercises during laboratory time. They quickly become proficient users of Google Earth and learn to easily exchange their ideas, answer the assigned questions, and pose their own questions to the instructor by attaching Google Earth (.kmz or .kml) files to emails.

SEMESTER-LONG PLACE-BASED GROUP PROJECT

Our initial assessment of the introductory geology course resulted in two main directives: (1) to improve students' understanding of how class content relates to their local surroundings and (2) to create a scaffold to help students make better connections between different geologic topics. To accomplish both goals, we created a semester-long group project that gave students multiple opportunities to document how different geologic topics related to a satellite image of northern California (Fig. 1). Throughout the fall 2008 semester, we integrated this group project into the lecture and laboratory setting by introducing each geologic topic alongside the satellite image and the topic's assigned area and question(s).

Students were prompted to think about how each topic introduced in the lecture and laboratory related to features on the satellite image of northern California and to make connections to these features based on their own prior experiences. By associating each geologic topic to a pre-established area on the satellite image (Fig. 1), students could incorporate their prior knowledge and experience by linking each geologic topic to a familiar place.

For the semester-long project, students in groups of two to three were asked to choose from a selection of key topics for detailed study and to focus on answering the specific questions relevant to their topic. For specific questions corresponding to each topic listed below, see Appendix A. The geologic topics to choose from include the standard textbook subjects taught in most introductory geology courses:

- Earth materials
- Igneous environments
- Sedimentary environments
- Metamorphic environments
- Structural geology
- Mass wasting and soils
- Plate tectonics
- Earthquakes
- Groundwater
- Rivers
- Shorelines

Each topic was accompanied by its unique assigned place on the satellite image, and the groups were responsible for the following three deliverables: (1) a Google Earth overlay file highlighting and labeling specific features that address the assigned area, (2) a PowerPoint digital poster displaying a "concept map" of the topic with the satellite image as the centerpiece of the presentation, and (3) a 10-min presentation to the laboratory class using their Google Earth overlay map and the PowerPoint digital poster. During the presentation, each group was required to illustrate how their topic connected to at least two other topics as well as present their own "essay test-style" question that involved multiple topics and areas on the satellite image.

Google Earth Overlay Map

Students were asked to highlight specific areas on Google Earth to showcase how their topic related to their assigned area and question. They accomplished this by outlining specific features, labeling those features, and writing small text blocks describing why they were significant. Students were asked to remain focused on the specific question, but agreed upon deviations were allowed.

We provided students with a Google Earth polygon of the assigned areas and examples of overlay images that could be draped on the topography and made transparent. The text blocks were brief, and the placemarks, lines, polygons, and overlays were well labeled, making it easy to turn each item on and off in the legend sidebar menu. For each item that they created, students could preselect the best scale and 3-D perspective to demonstrate their point.

Students emailed their final Google Earth's file formatted file to the instructor before their presentation date. The

Google Earth portion of the group project was graded on how well the student demonstrated the relevancy of their topic to their question, the connections with other topics, and the overall organization of the various features that were highlighted on Google Earth. Examples of both good and poor overlays are shown in Fig. 2.

"Concept Map" Place-Based Poster

Using the satellite image as its centerpiece, the PowerPoint "concept map" was used as a graphic organizer in the form of a digital poster (e.g., Geological Society of America-style poster). The concept map design encouraged students to link images, information, and geologic concepts to the map, making connections between conceptual models and real-world examples. Although there was some overlap with the Google Earth overlay, students had the freedom to research various sources, including the textbook's Web site, utilize their own experiences, and place any image or idea in the context of the satellite image and their assigned area and question(s). We provided a framework template for the digital poster to focus the students' efforts (Fig. 3).

Ten-Minute Group Presentations

Students presented their Google Earth file and their PowerPoint digital poster to their peers during the laboratory class. During the presentations, the students made connections to at least two other topics. Each group also created a new question that showcased an ability to make connections between the group's topic and other topics, and the ability to use another place in northern California (in the image) as a basis for the question. Students were encouraged to construct questions that could not be answered with a one-phrase response, but rather to ask questions that required the synthesis of ideas or fundamental geologic concepts. The presentations and questions students constructed were not graded. The purpose of the presentation was for students to build confidence in their ability to present their work and share ideas with their peers. The presentation also helped students to reinforce how geologic concepts and processes they presented were related to other students' topics and fundamental geological concepts.

ASSESSMENT AND EVALUATION

Geoscience Concept Inventory

As a basic means of evaluating the effectiveness of the changes to our course materials and teaching strategies, students completed an online pre- and postcontent knowledge test during the first and last week of each semester of the study. Questions for the tests were selected from the Geoscience Concept Inventory (GCI) version 1.0, an assessment instrument developed by Libarkin and Anderson (2005) for the diagnosis of alternative concepts and assessment of learning in entry-level earth science courses. GCI version 1.0 consists of an online database of 69 validated questions that instructors can select from to use in their course. The criteria that were used for the selection of questions were based on the consideration that the topic areas be representative of the geological content and processes covered in this course. Test results collected from the spring 2008 semester provided a baseline with which to compare students' learning during the initial course redesign (fall 2008) and after the final iteration of the course redesign (spring 2009).

As shown in Fig. 4, the class average pretest scores ranged from a low of 47.2% to a high of 59.7% indicating that, on entering the class, most students had a very minimal understanding of fundamental geological concepts and processes. For each semester, normalized learning gains were calculated based on changes from pre- to posttest scores. In addition, a Wilcoxon signed rank test was used to determine the significance of this gain. As would be expected, results indicated that the class had a very significant effect on the students' understanding of the topics covered in the GCI tests. Notable though is that the class average–normalized gains for the two semesters taught using a place-based approach (fall 2008 and spring 2009) were noticeably higher than the gain for the baseline semester (spring 2008). In fact, the greatest gain was seen in the third semester (spring 2009) when the curriculum design and implementation of instructional strategies were in full effect. The results showed more than twice the normalized learning gain: 31.1% compared to only 14.1% learning gain for the baseline semester (Fig. 4b). An independent samples *t*-test between spring 2008 and spring 2009 confirms that this measured increase in normalized learning gain is highly significant ($p = 0.027$).

Semester-Long Place-Based Group Project

The place-based group project was part of the revised class curriculum and was only implemented during the fall 2008 and spring 2009 semesters. At the end of theses semesters, the projects were scored using a performance-based rubric (Appendix B). A key consideration in the evaluation of the project was the assessment of the students' ability to make connections between their assigned topic and geological features depicted on the satellite image of northern California. As shown in Fig. 5, the overall class average group project score for the spring 2009 semester was slightly higher then the class average score for the fall 2008 semester, although the difference was not statistically significant. Similarly, the assessment category scores indicate several areas of students' learning that showed improvement, including the quality of the overlays (see Appendix B for a complete description of the category attributes), relevance to the satellite image, and connection to topics; the scores, however, were not statistically significant.

We make the assumption that the differences between the two semesters can be explained by the lessons we learned from the pilot study (fall 2008). For the fall 2008 group project, we only assigned a general topic to each group and asked the students to show how their topic connected to the other topics. They could demonstrate how their topic was relevant to the satellite image through two methods: (1) a PowerPoint concept map poster and (2) a Mylar overlay map that the students needed to superimpose physically on the satellite image. Notably missing in the fall 2008 (pilot study) semester-long project was the use of Google Earth and questioning strategies that targeted the specific areas on the satellite image.

The second iteration of the semester-long group project, implemented during the spring 2009 semester, was warranted by the outcomes of student learning during the fall 2008 pilot study. To address our concerns that students seemed to compartmentalize geologic concepts and pro-

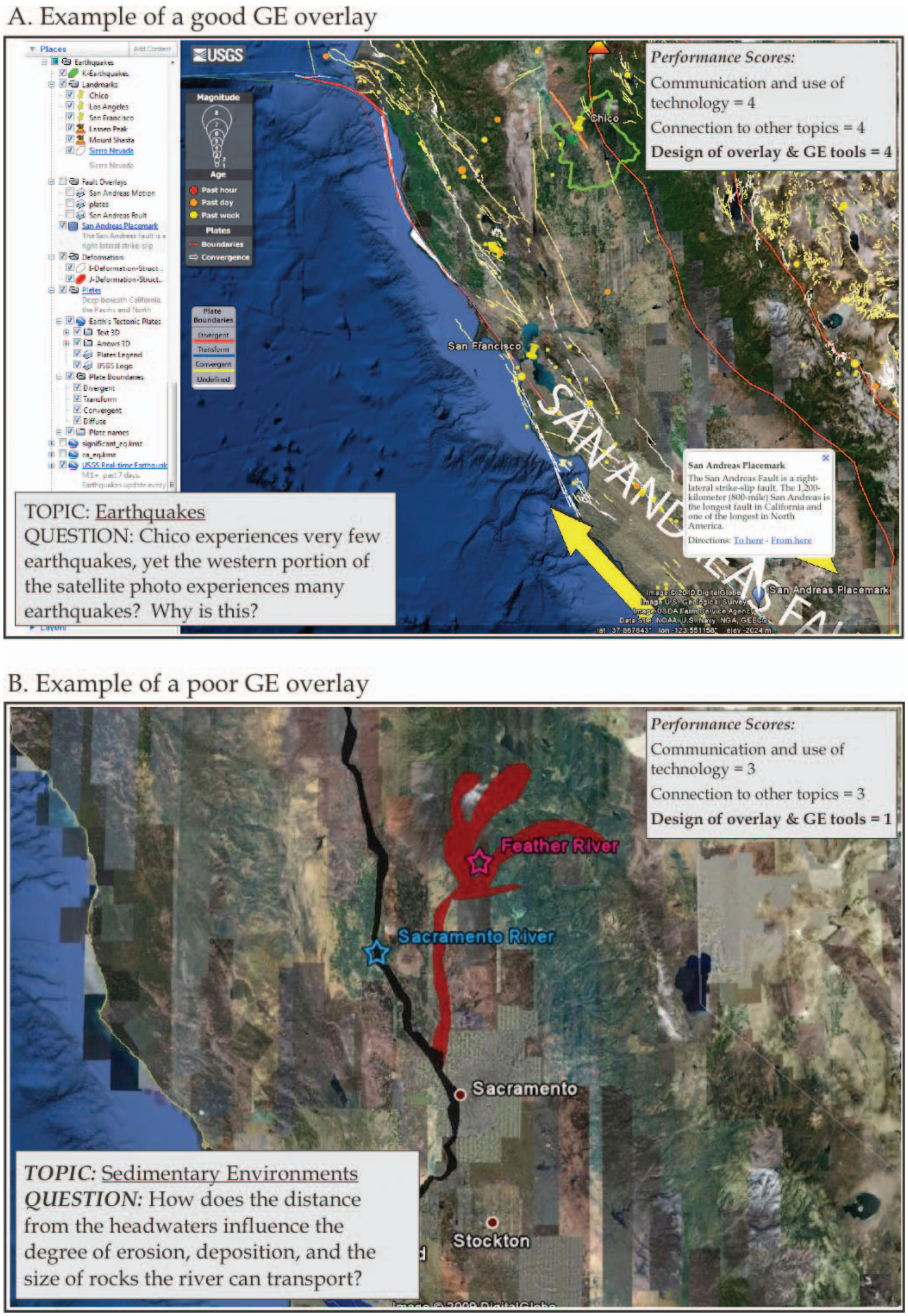

FIGURE 2: Google Earth overlay examples. (A) Example of a good Google Earth overlay. Note the use of Google Earth tools (text blocks, polygons, lines, and placemarks) to effectively address the question and their subject matter while making good connections to other topics (plate tectonics and deformation). During their presentation, the group used the Google Earth menu (on left) to highlight various features and change the scales and 3-D perspectives.

cesses as isolated bits of information, independent from one another, and that they were not able to apply, identify, or explain the relationship between their topic and major features on the satellite image, we included the following adjustments. First, we focused the students' efforts by having them present on a particular question and area on the satellite image. Second, as they became more comfortable with their topic/area/question, we then asked the students to build upon this knowledge to expand to other areas and topics by having them create a follow-up question that showcased their ability to use another place in northern California (in the image) as a basis for their new question. Third, we changed the satellite image we used for the group project from a sideways perspective view of northern California (fall 2008) to a sharper, higher resolution, more vibrant image with a straight-down map-view perspective of the same area. Fourth, to better utilize map-based technology, we replaced the Mylar overlay with a Google Earth overlay. Replacing the Mylar overlay not only cut down costs, but it also allowed for a freer exchange of ideas because the Google Earth overlay file can easily be emailed to and from the instructor for faster feedback. Fifth, we infused the group project goals into the lecture portion of the class. We introduced each topic in the lectures by first displaying the satellite image and the question and area for that particular topic.

Place-Based Examinations

In addition to the GCI pre- and posttest, a place-based pre- and postexamination was given to the students at the beginning and end of the spring 2009 semester. The examination questions were purposefully designed to challenge students thinking beyond the memorization of facts by encouraging them to identify geological features depicted on the satellite image of northern California as evidence to support their claims. The significance of providing a satellite image was to help build a sense of place to geographical areas in northern California by reinforcing concepts learned in class with real-world connections in the local and regional landscape. This was the same satellite image used in the lecture and laboratory to introduce and connect topics (Fig. 1). It also functioned as a visual tool, helping students to conceptualize how concepts were connected across topics and providing evidence to support big picture ideas such as plate tectonics.

The rubric, shown in Table I, was used to assess the students' content knowledge (C) and ability to use critical thinking skills by providing evidence (E) from the satellite image to support their reasoning. An interrater reliability test was performed using a joint-probability agreement method to determine the consistency of the scoring rubric. The first instructor scored each question response, focusing on one question at a time. The second rater independently coded 20% of the total question responses. The prediscussion interrater reliability between the two coders was 85%. After the raters discussed the results, 100% agreement was achieved.

Scores from the pretest indicate that on average students entered the semester with the lowest content knowledge in the areas of metamorphic environments and plate tectonics (Fig. 6A). However at the conclusion of the semester, the content knowledge scores were not only demonstrably higher, but were also fairly consistent across topic areas. The overall class average gain from pre-to postexamination scores showed a significant gain in both the correct answer and their ability to reason from evidence, and Fig. 7 shows a distinct correlation between gains in evidence and content knowledge. The trend suggests not only the importance of challenging students to provide the correct answer but also the importance of reasoning from evidence to support their claims.

DISCUSSION AND IMPLICATIONS FOR TEACHING

The findings suggest that the structured use of satellite imagery combined with Google Earth can help to scaffold student learning of fundamental geological concepts and processes. Creating a sense of place helps students to revisit the concepts that they learn in class, make connections between topics, and apply this knowledge to interpret the geologic processes that shape the environment. We found that when students are given the resources and opportunity to apply what they learned in class to the local environment, not only did they gain a better understanding of the concepts and how they link to other places, but they also began to see the relevancy of seemingly abstract concepts to their lives outside the classroom.

As an example, most students in our classes are aware, to some degree, about the hazards associated with gold mining in northern California. However they are much less aware of where the mercury was originally mined before being used to separate gold. The metamorphic environments question (Appendix A) asks students to connect the location of mercury mines to areas where recent volcanic rocks are in close proximity to serpentinite: north of Napa and Sonoma valleys. Students are encouraged to investigate the cause of this connection (contact metamorphism of serpentinite by magma that fed the recent volcanoes) and to determine that mercury is a by-product of this process. By making this connection, students are not only more informed about local environmental issues, but they are better equipped to explain the geologic processes behind the origin of the pollutants.

It is important to note that simply assigning local topics to investigate did not necessarily lead to a better understanding of the connections between them. We found that students must also be encouraged to reflect on their learning in ways that fostered a higher level of thinking. An example is seen between the first (fall 2008) and final (spring 2009)

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(B) Example of a poor Google Earth overlay. Although this group scored well using their PowerPoint poster (not shown), their Google Earth overlay did not showcase any of their connections to other topics, made poor use of Google Earth tools, and did not use the Google Earth menu (not shown) during their presentation to change the scales or perspectives. Note: Light grey boxes are comments to the reader explaining the topic of investigation as well as the performance scores given by the instructors based on the rubric shown in Appendix B.

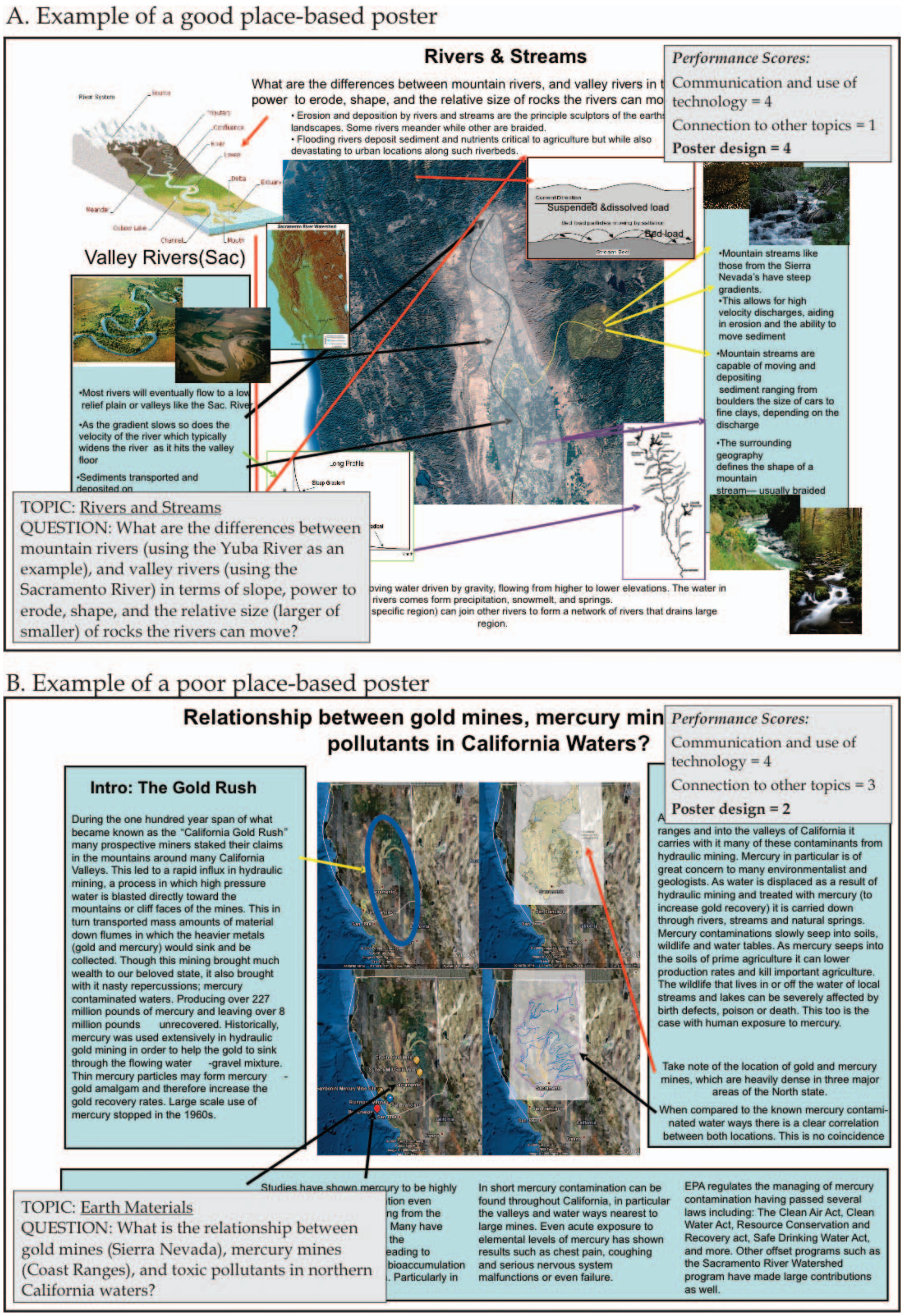

FIGURE 3: Examples of the place-based concept map poster. (A) Example of a good poster design. Although the group scored low for connections to other topics, their poster showed a good understanding of the concept map design (poster design score = 4) by relating images and concepts to each other as well as the centerpiece satellite image. (B) Example of a poor poster design. Although this group presented good information that addressed their question well, they had too much text and did not include images that explained concepts or local features. Note: Light grey boxes are comments to the reader explaining the topic of investigation as well as the performance scores given by the instructors based on the rubric shown in Appendix B.

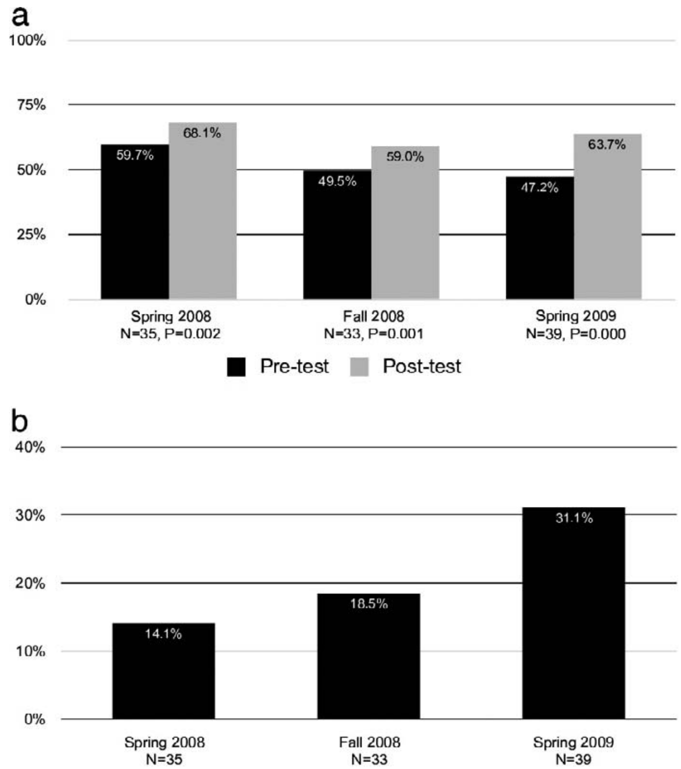

FIGURE 4: Scores from GCI tests. (a) Class average pre- and posttest scores by semester (p values less than 0.050 are considered statistically significant gains). (b) Class average normalized gains by semester. Independent samples t-test between spring 2008 and spring 2009 showed differences in normalized gains to be highly significant ($p = 0.027$).

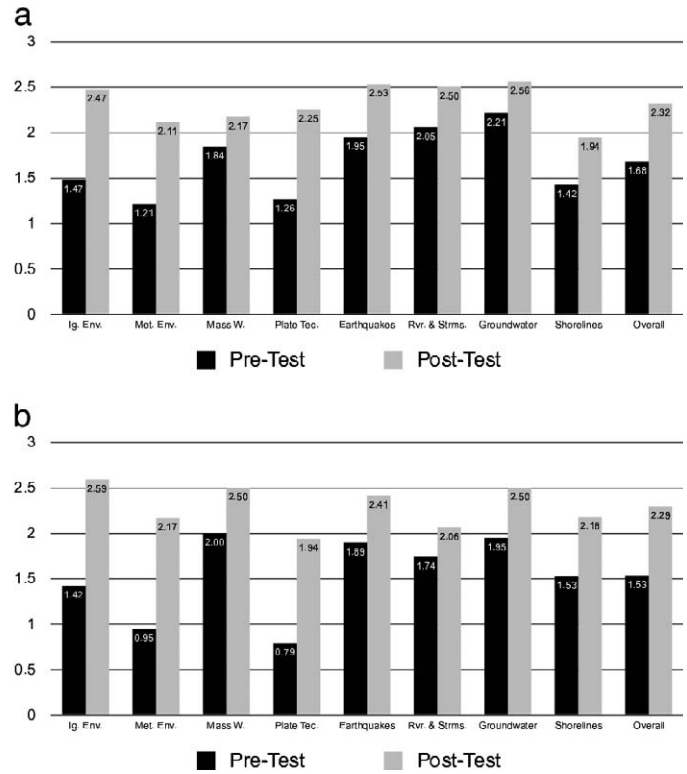

FIGURE 6: Pre-and posttest place-based scores (spring 2009). (A) Upper chart shows content knowledge scores. (B) Lower chart shows the reasoning from evidence scores. Each are arranged by topic and based on the rubric explained in Table I for each of these criteria.

iterations of the semester-long project. In the final revision, we included focus questions that prompted students to further reflect on the connections between topics by explaining the processes and then to use evidence from the satellite image of northern California to support their claims. By prompting students to reason from this evidence, we found that they not only gained a deeper understanding of the subject matter, but their ability to make connections between topics improved.

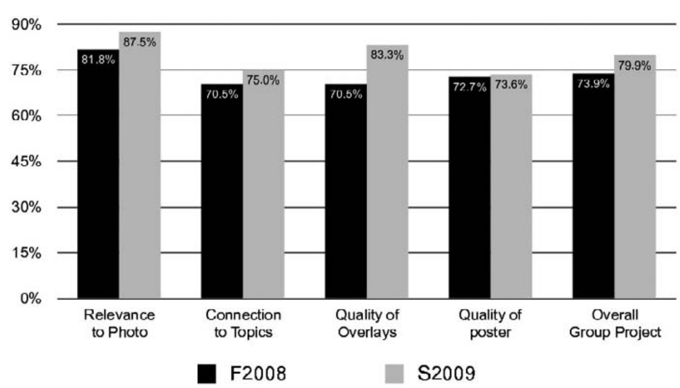

FIGURE 5: Class average place-based project assessment category scores.

Technology was used as a tool to support student learning, not as the main focus of the class. We had initially made the assumption that students would be able to use these tools without previous instruction; however, student feedback and results from the group project during the pilot semester suggested that this was not the case. To maximize their use of Google Earth and satellite imagery, we learned that it was imperative to provide an overview and an introductory assignment on how to use the technology.

One of the potential limitations for implementing this strategy could lie in regions that offer less diverse geologic examples of basic concepts. The lack of meaningful local places where the terrain does not demonstrate typical

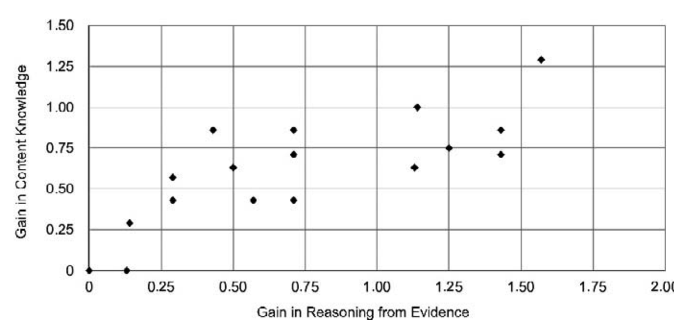

FIGURE 7: Gains in content and evidence scores from pre- to posttest. Correlation coefficient $R = 0.783$.

TABLE I: Scoring Rubric for Place-Based Exam.

	Group Scores			
Criteria	**3**	**2**	**1**	**0**
Content knowledge	Gives an accurate explanation and all the important points are included	Gives a reasonably clear explanation and most of the important points are included	Gives an explanation that is not correct or a limited number of important points are included	No explanation is attempted
Reasoning from evidence (from satellite image)	Provides good examples from the satellite image as evidence to support their explanation	Provides limited examples from the satellite image as evidence to support their explanation	Provides poor examples from the satellite image as evidence to support their explanation	Provides no examples from the satellite image as evidence to support their explanation

geologic subjects may either limit the topics that a course can cover using our strategy or it may force the instructor to use places that are less meaningful to the students (e.g., from outside their region). In these cases, we suggest that instructors look beyond the exposed geology of their region and rather use historical reconstructions of their local area to demonstrate key geologic principles. For example, areas that contain seemingly monotonous landscapes that were recently covered by Pleistocene ice sheet deposits (e.g., midwestern U.S.) usually have a rich geologic history underlying the surface. This history can include continental scale collisions and rifted margins, widespread volcanism, or voluminous igneous intrusions. Connecting this history to local places may help foster place-based strategies in less geologically diverse regions.

In summary, this study provides a number of useful insights about students' learning in an introductory physical geology course by revealing that students often have difficulty making connections between topics and synthesizing key concepts to interpret how geologic processes shape the characteristics of the local and regional natural environment. The findings suggest that, when given the opportunity and tools to develop a sense of place, students improve their conceptual knowledge and ability to apply critical thinking skills and their learning becomes more meaningful and relevant to their everyday experiences.

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APPENDIX A. Question(s) Corresponding to the Polygons on the Satellite Image of Northern California (Fig. 1).

Topics	Questions
Earth materials	a) What is the relationship between gold mines (A1 and A2) and mercury mines (B), and how does this affect the water quality of the water in the region of (E, F, G)? b) What is the connection between the location of mercury mines (B) and recent volcanic rocks in the Clear Lake/Napa/Sonoma area (B1)?
Igneous environments	a) Most of the granites of the Sierra Nevada (A1) are around 100-million-years old, but no younger than 80-million-years old. However, Lassen Peak (C) and Mt. Shasta (D) are very young (less than 1 million years old). What geologic processes have created the rocks associated with areas (A1, C, & D)? b) Are the Cascades Mountains (to the north in Oregon and Washington) more similar to the granites of the Sierra Nevada (A1) or Lassen Peak/Mt. Shasta (C/D)? What is the evidence that supports your answer? c) Two popular tourist destinations in the Modoc Plateau (D1) are the Lava Beds National Monument (made up of basalt; think Hawaii-type lava flows) and Medicine Lake Volcano. Both the Lassen Peak and Mt. Shasta volcanoes (C/D) are comprised of steep slopes, however the Medicine Lake Volcano (D1) is relatively flat. Why is that?
Sedimentary environments	a) If you were able to take samples of river sediment from G (Feather River) to F (Sacramento River) to E (San Francisco Bay), you would find that quartz and feldspar are the main types of minerals found in the sediment samples. However, the percentage of feldspar and quartz found in each sample varies as you travel from G to F to E: there is a decrease in the amount of feldspar and an increase in the relative amount of quartz. How would you explain this considering that all of these samples came from the same rock type at the headwaters of the Feather River? b) What is the connection between this rock type and the dominant rock type in area (A1)? c) How was that rock type formed?
Metamorphic environments	a) The Coast Ranges are mostly made of serpentinite, the state rock of California. Serpentinite is created by metamorphosing rocks that make up the basement underlying ocean floors. The basement rocks that underlie ocean floors are hard crystalline rocks that are buried miles beneath the softer ocean sediments. How do you explain the occurrence of metamorphosed ocean basement rocks as far inland as the mountains of the eastern Coast Ranges (B2)? b) What is the relationship between the serpentinite in the Coast Ranges (B2) and the locations of the mercury mines (B) and the recent volcanic rocks of B1?
Mass wasting and soils	a) The circled area (H) contains a very high concentration of landslides. Why is this area so landslide prone? What are the geological and biological features that make this area especially prone to landslides? b) What is the connection between this landslide-prone area and the rocks in area B2? c) Compare the circled area to the area along the Sacramento River (F). Why do you think there is a greater diversity of agriculture in the Sacramento River area than the circled area (H) to the west?
Structural geology	a) The circled area (J) shows the trace of the San Andreas Fault. The slice of land that is circled just to the west (I) of the San Andreas Fault has rocks as old as 50 million years. The very same rocks are also found on the east side of the San Andreas Fault, but much farther south (off the photo in southern California). If you believe this scenario to be true (which you should), then describe if the North American side of the San Andreas Fault is moving south or north relative to the Pacific Ocean side. b) Why does the north tip of the San Andreas Fault end abruptly at Cape Mendocino (J2)?
Plate tectonics	a) The San Andreas Fault (J) is a major plate tectonic boundary that currently divides the North American Plate from the Pacific Plate. What is the evidence on the photo that supports there was another type of plate tectonic boundary in California before the San Andreas Fault existed? b) What is the connection between areas A1 and B2 to this other type of plate boundary?
Earthquakes	a) Chico (K) experiences very few earthquakes, yet the western portion of the satellite photo experiences many earthquakes. Why is this? b) What evidence is there on the northeastern portion (D1) of the photo that earthquakes happen much more frequently than they do in Chico?
Rivers	a) What are the differences between mountain rivers (using the Yuba River (L) as an example), and valley rivers (using the Sacramento River (F)) in terms of slope, power to erode, shape, and the relative size (larger of smaller) of rocks the rivers can move?
Groundwater	a) If Chico (K) pumps its water from wells that are located within the town of Chico, why do we care about the circled area (M) in terms of rainfall, rivers, and groundwater? b) If you assume the type of rock that Chico's groundwater travels through is the same type of rock that is located in area M, what type of rock do you think this is? (Area C is a clue.) c) Would this be considered an easy type of rock for groundwater to travel underground through or a difficult rock to travel through? Why?
Shorelines	a) If global sea level dropped below today's level (which it did only 18,000 years ago), where would the new coastline be relative to today's coastline (west or east of the current coastline (O))? b) In what ways would this affect the river systems (N) that drain into the coastline in terms of erosion and/or deposition? c) What is the most likely cause of a global lowering of sea level?

APPENDIX B. Scoring Rubric for Semester-Long Group Project.

Performance	4	3	2	1
Communication and use of technology	Topic and question is thoroughly described and information is concise; excellent use of Google Earth and PowerPoint poster in highlighting the relevance of the significant features on the satellite image	Topic and question is adequately described and information is concise, or topic and question is well described but information is too lengthy; good use of Google Earth and PowerPoint poster in highlighting the relevance of the significant features on the satellite image	Topic and question is poorly described and information is missing; fair use of Google Earth and/or PowerPoint poster in highlighting the relevance of the significant features on the satellite image	Topic and question is poorly described and information is missing; poor use of Google Earth and/or PowerPoint poster in highlighting the relevance of the significant features on the satellite image
Connection to other topics	Identified and thoroughly explained 2+ connections to other subject matter topics, relevant to main topic and question; excellent use of text or images to explain connections	Identified and briefly explained 1–2 connection(s) to other subject matter topics relevant to main topic and question; good use of text or images to explain connections	Identified and briefly explained 1 connection to another subject matter topic but not relevant to the main topic and question; poor use of text or images to explain connections	No connection to another subject matter topic
Design of Google Earth overlay and tools	Overlay illustrated excellent examples of subject matter relevance and, highly organized; demonstrated excellent use of Google Earth tools (polygons, place marks, paths, and overlays); and demonstrated an excellent understanding of spatial referencing using Google Earth functionality	Overlay illustrated good examples of subject matter relevance and well organized; demonstrated good use of Google Earth tools; and demonstrated a good understanding of spatial referencing using Google Earth functionality	Overlay illustrated fair examples of subject matter relevance and fairly organized; demonstrated fair use of Google Earth tools; and demonstrated a fair understanding of spatial referencing using Google Earth functionality	Overlay illustrated poor examples of subject matter relevance and poorly organized; demonstrated poor or no use of Google Earth tools; and demonstrated no understanding of spatial referencing using Google Earth functionality
Poster design	Excellent poster design, illustrating a concept map format and showing connections (e.g., arrows) between images/text; relevant features on the photo were effectively highlighted and explained using images and concise text	Good poster design, illustrating a concept map format and showing connections between images/text; relevant features on the photo were adequately highlighted and explained using images and text	Fair poster design but did not follow a concept map format; relevant features on the photo were highlighted but poorly explained using images and text	Poor poster design did not follow a concept map format; relevant feature on the photo were not highlighted or explained using images or text