Introducing Teachers to Geospatial Technology while Helping Them to Discover Vegetation Patterns in Owens Valley, California

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ABSTRACT

A field course attended by science teachers in California's Owens Valley incorporated geospatial technology to reinforce the relationship between elevation, aspect, or the direction a mountain slope faces, and vegetation. Teachers were provided GPS units to record locations and plant communities throughout the 9-day field course. At the end of the field course, they completed an exercise utilizing ArcGIS and/or Google Earth. A similar essay question about vegetation and elevation was answered at the beginning of the course and after the GIS/Google Earth exercise. Scores on this pre- and post-activity question as well as responses to a survey questionnaire indicate that GIS and Google Earth both helped the teachers understand how elevation influences vegetation. The role of aspect was not as well demonstrated in the post-test responses as that of elevation. Teachers reported being more likely to use Google Earth in their classrooms than GIS (75% to 58.3%). Combined with GPS, Google Earth provides a free, easy and flexible way to teach a number of earth science concepts and meet several National Geography Standards.

INTRODUCTION

Among the 18 National Geography Standards are the ability to understand the world in spatial terms (Standard 1: how to use maps and other geographic technologies to acquire, process and report information, and Standard 3: how to analyze the spatial organization of environments) and the ability to understand physical systems (Standard 7: the processes that shape earth's surface and Standard 8: the distribution of ecosystems on earth's surface) (Geography Education Standards Project, 1994). There are many ways to incorporate geospatial technology, such as GPS (Global Positioning System), GIS (Geographic Information Systems) and Google Earth into the classroom to meet some or all of these standards. Much has been written about the use of geospatial technology in the K-12 classroom to help teach some of these standards. A common thread in much of the literature on incorporating GIS or other geospatial technologies into the K-12 classroom is that teachers have historically not been shown how to incorporate this technology. Rather, training has focused on how to use the technology and not how to use the technology to teach (Bednarz and Ludwig, 1997; Kerski, 2001). Building on this idea, the activity created for science teachers on a nine day field course discussed below was designed with several objectives.

The first objective was to introduce students to geospatial technology through a data collection and analysis exercise they could do with their own students. To help fulfil the meteorology and environmental science aspect of a field course, the next goal of the activity was to help students develop an understanding of the relationship between elevation, plant community and aspect, or the orientation of a mountain slope. This objective was measured by student performance on an essay question answered both before and after the activity. Finally, a survey was administered to determine if students were familiar with geospatial technology and whether they used it already or planned to use it in their classroom. The survey also served as an evaluation of the activity to help the instructors plan for future offerings of the course. Results from two years of doing the activity on the field course indicate that this activity can be taught using GPS and either GIS or Google Earth, depending on the teacher's preference or resources and also suggest that Google Earth may be a more accessible means for teachers to accomplish the same goals regarding some of the National Geography Standards.

Geospatial technology and K-12 instruction

Reasons to integrate geospatial technology in K-12 schools include the ability to study local problems in depth, to analyze environmental change and to enhance student interest through the use of technology (Lemberg and Stoltman,

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1999). There are many examples of this being done at schools in a variety of different ways and at multiple grade levels. For example, GPS and mobile GIS have been incorporated into a structural geology class at the college level (Neumann and Kutis, 2006), web-based GIS activities have been used with pre-service teachers to investigate a series of local environmental issues (Bodzin and Anastasio, 2006), and seventh and eighth grade students used GIS in a water quality lesson (Meyer et al., 1999). GIS and GPS were also combined in a program sponsored by the Grant Wood Area Education Agency in eight Iowa school districts. During the second phase of this program, teachers and students used this technology to propose research questions and develop a process to scientifically address those questions, which included the collection of water quality data (Grant Wood Area Education Agency, 2006). Baker (2005) stressed the importance of students collecting their own data to examine in the context of other data.

A common benefit that results from the integration of geospatial technology is improved map-skills (Neumann and Kutis, 2006; Weiss and Walters, 2004). A project completed with fourth graders showed GIS helped the class to think more geographically (Shin, 2006). GPS can also be used as a tool to accommodate different levels of intellectual development and different learning styles (Broda and Baxter, 2002). GIS and GPS have been used to build environmental literacy by enabling students to collect and analyze water quality and other local data (Lo et al., 2002). Other benefits resulting from GIS use have included a better ability to identify and explain human and physical patterns on the earth, increased place knowledge (Kerski, 2003) as well as improved attitudes about analyzing scientific data and making decisions with it (Baker and White, 2003).

Much of the literature has focused on GIS, but this is not the only geospatial technology that can accomplish some of the previously mentioned goals. A technology well-suited for the display and sharing of data to illustrate scientific concepts for Baker (2005) is Internet-based mapping. Access to hardware and the time required to learn GIS software have been identified as barriers to its incorporation into the K-12 classroom (Meyer et al., 1999). Internet-based mapping, which requires both server and user to produce and manipulate a map through a Web-browser, has been offered as a solution for teachers who wish to incorporate mapping without spending the time necessary to learn a software system (Baker, 2005).

One type of Internet-based mapping is the Virtual Globe recently discussed by Schultz et al. (2008). A virtual globe allows the user to visualize the earth in 3D by flying above it and exploring different data sets on the earth's surface (Schultz et al., 2008). One of the most commonly use virtual globes is Google Earth. There are very few academic papers published on the use of Google Earth, however, this free software has quickly become popular, downloaded over 350 million times by users throughout the world according to Google Earth Program Manager, Chikai Ohazama (2008). Its popularity has given Google Earth considerably more "mindshare" than GIS, which may help make people aware of the "power of mapping" (Crampton, 2006). The strength of Google Earth lies in its ability to clearly display and explore geographic data while not requiring the user to possess advanced skills (Schultz et al., 2008), which was one of the criticisms of GIS software (Meyer et al., 1999).

Because little research has been conducted on Google Earth, there are many unanswered questions, including whether this is a piece of software teachers are familiar with or a technology they use in their classrooms. The activity discussed in this paper will also determine whether it is a technology that can be used to teach a simple lesson about the relationship between plant type and elevation. The activity and survey discussed below attempted to answer these questions.

THE ACTIVITY

Students taking part in the project were enrolled in a master's degree program in Geosciences for teachers. As part of the degree, students must attend an 8-10 day field course in one of several locations, including the Eastern Sierra Nevada, where this activity took place. (See map, Figure 1). On the first night of the field course, the activity was explained to students and the students were given a pre-activity essay question that asked them to describe the differences in vegetation they expected to see throughout the trip, along with questions regarding whether they had ever used a GPS unit, GIS and Google Earth.

During the field course, students were given GPS units to record location along with one of eight plant communities. There were approximately 40 sites at which the group stopped, primarily selected by the lead instructor for their geological significance. Students were

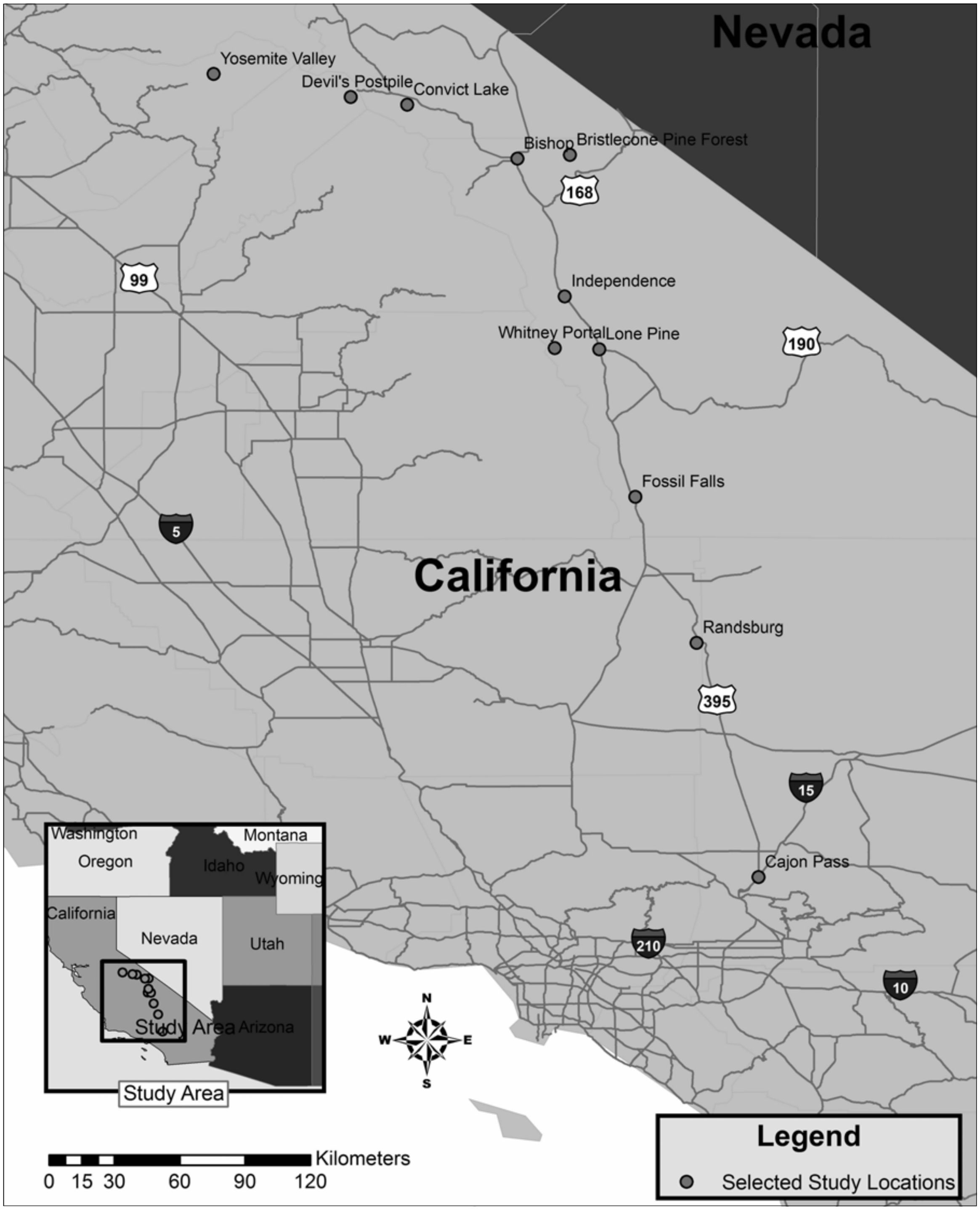

Figure 1. Map of the field course area with a selection of study locations shown.

free to choose when to record a GPS point, and were not required to make an observation at every stop. The plant communities the students recorded with each GPS observation were based on those discussed in several publications (Puttnam and Smith, 1995; Barbour and Major, 1977; Munz and Keck, 1955). A handout showing color images of the 8 plant communities was provided at the introductory meeting.

The field course began in Ontario, California and traveled northeastward to its final destination in Yosemite National Park. Over the course of the field study, students were exposed to a number of microclimates and plant communities. Most locations had one dominant plant community. The primary control of vegetation in east central California and much of the western United States is elevation. The higher the elevation, the greater the precipitation and, therefore, plant communities that require more water are more prominent at higher elevations. The Sierra Nevada, extending from the northwest to southeast, blocks most of the moisture moving inland from the Pacific leaving a rain shadow in the lee of the mountain range. This rain shadow effect results in much lower precipitation on the eastern slope of the Sierra Nevada. To a lesser extent, a similar phenomenon occurs on the White and Inyo Mountains to the east of the Owens River. Other factors contributing to the distribution of plant life include the orientation of mountain passes and the aspect of hillsides. The lower limits of growth for plant communities tend to be lower on north-facing slopes and higher on south-facing slopes (Klyver, 1931), and some plant communities can be found on the eastern slopes of the Sierra and not on the western slopes of the White/Inyo and vice versa (Barbour and Major, 1977). Students began the trip with the basic understanding of concepts such as the environmental lapse rate (how quickly the temperature decreases with altitude) and the rain-shadow effect. The dramatic effect elevation and aspect has on vegetation in the Sierra Nevada and White and Inyo Mountains, however, is usually a learning experience for the students.

By the end of the sixth field day, students had assembled a list of the GPS coordinates for the whole field course along with their plant communities. At this point, the remainder of the activity varied from 2007 to 2008. In 2007, this text file was imported into ArcGIS and Google Earth and the class gathered to view an ArcGIS and Google Earth presentation, which allowed them to visualize where they had been and what vegetation they had seen. Figures 1 and 2 show examples of what was projected for the students to see. The students did not have access to individual computers, so the whole program was projected as shown, and not just the maps so that students could see all the tools and options available. The ArcGIS portion of the assignment included the display of a colorized elevation contour map (Figure 2), onto which the vegetation points were plotted. Questions included at what elevation various types of vegetation were located. The points were then added to Google Earth (Figure 3). Similar questions were asked. Finally, students answered a post-activity essay question similar to the one they were asked on the first day of the course. They were also asked to sketch the distribution of plant communities on a blank cross section of the Owens Valley.

Following the presentation and exercise, the students answered several survey questions about the activity and whether they might use geospatial technology in their classrooms.

In 2008, the instructors decided to eliminate the ArcGIS portion from the activity. The students in the previous class had been so much more interested in Google Earth, and their feedback on the evaluation (to be discussed later) led the instructors to believe it might not be worth the time to go over ArcGIS since the students would not be able to learn the software in such a short time. The presentation was modified such that the questions were very similar, but the colorized elevation contour map was added to Google Earth rather than ArcGIS. One other difference was that the 2008 activity used 2007 data with only a few new points from 2008 added. The instructor did this to save time, but students later commented that they would rather have seen all of their own data. The rest of the activity was the same. Since the activity was completed on a field course, the students did not have access to computers themselves; therefore in both 2007 and 2008, the instructors guided the students through the exercise questions by projecting either ArcGIS or Google Earth onto a flat white surface. Students completed the final post-activity essay question individually.

RESULTS

Results discussed below were based on two sessions of the same course, run in June 2007 and June 2008. The course was attended by 16 students in 2007 and 14 students in 2008. For whatever reason, some students did not answer every question, and two students in 2008 chose not to sign consent forms and their assignment papers were not included in the results. Because this constituted a sample of convenience, the following results may not be generalizeable to all science teachers, or even to all students enrolled in this degree program.

Results (see Table 1) show that students came into the class already being familiar with Google Earth (85.2% had used it before). Much smaller percentages had used GPS and GIS technology (39.3% and 18.5%). Even though less than half of the students had prior experience with a GPS unit, all students who answered the question said they felt comfortable using the GPS unit by the end of the field course, and 70.8% thought they might use GPS in their classrooms. Only a little more than half of the 2007 students to whom this question was asked thought they might be able to incorporate GIS activities, but 83.3% believed they could use Google Earth. Students' reasons for the

Question		GPS	GIS	Google Earth
Have you used GPS/GIS/Google Earth before?	Yes No	11 (39.3%) 17	5 (18.5%) 22	23 (85.2%) 4
Did GIS/Google Earth help you visualize the relationship between elevation, aspect and vegetation?	Yes No	N/A	11 (92%)* 1	23 (100%) 0
Do you think you might use GPS/ GIS/Google earth in your classroom?	Yes No	17 (70.8%) 7	7 (58%)* 5	18 (75%) 6
*Since students were not shown GIS in 2008, they were not asked if GIS helped or if they thought they would be able to use it in their classrooms.				

Table 1. Responses to selected questions on evaluation.

		Pre-activity essay	Post-activity essay
Combined*	Average score	4.48	6.29
	Standard deviation	2.45	1.68
2007 only*	Average score	3.75	6.50
	Standard deviation	2.05	1.62
2008 only	Average score	5.33	6.04
	Standard deviation	2.68	1.79

Table 2. Scores on pre and post activity essay questions for 2007 and 2008. * Difference is significant at $p < .01$.

preference of Google Earth over GIS included that it was free, required little training and that the 3D tilting and flexibility built into Google Earth allowed them and their own students to easily visualize the data. The vast majority of the 2007 class said both GIS and Google Earth helped them to visualize the relationship between plant community, aspect, and elevation.

One way GIS helped students to visualize the relationship between vegetation and elevation that was cited multiple times was the classification of elevation by color. The color enabled students to see quickly which vegetation was at a certain range of elevation. This component was incorporated into Google Earth for 2008.

Students cited GIS's level of difficulty as their primary dislike of it. Most of the negative comments about Google Earth (5 out of 7) involved the lower resolution of a portion of the field study site that was partly the result of using a dial-up internet connection. The other two negative comments about Google Earth were that it would take time to learn or understand. Most of the negative comments about GIS were that is was hard to understand.

In addition to students' overall positive feedback on the activity, most scores increased from the pre-activity to post-activity essay question about the relationship between elevation, aspect and plant type. Each student's essay question was graded according to 10 criteria. These criteria included whether elevation was mentioned in the answer, if it was correctly explained how vegetation changes with elevation, whether the student differentiated between the Eastern slope of the Sierra Nevada range and the Western slope of the White-Inyo range, and so on.

Answers were given one point for each criterion, for a total of 10 points possible. Of the 26 students that turned in both pre and post-test questions, 73.1% better explained these relationships after completing the activity. Scores on the post-activity essay were also significantly higher for both 2007 alone (Wilcoxon Signed Ranks $Z = -3.05$, $p = .002$) and for both years combined ($Z = -3.18$, $p = .001$). See Table 2 for average scores on both pre and post activity essay questions. Scores on the 2008 pre-activity essay question were higher than 2007, but a few students' scores actually dropped from the pre-activity essay to the post-activity essay.

Possible reasons are discussed in the suggestion section and include the decrease in time allotted to the presentation, the alertness of the students, and the use of the previous year's data points. One student whose score decreased on the post-test question had scored the highest grade on the pre-test (based on a 10-point scale) and only earned one point less on the post-test question. Two students' scores increased by 7 points between the pre-test and the post-test. An example of the two responses appears below.

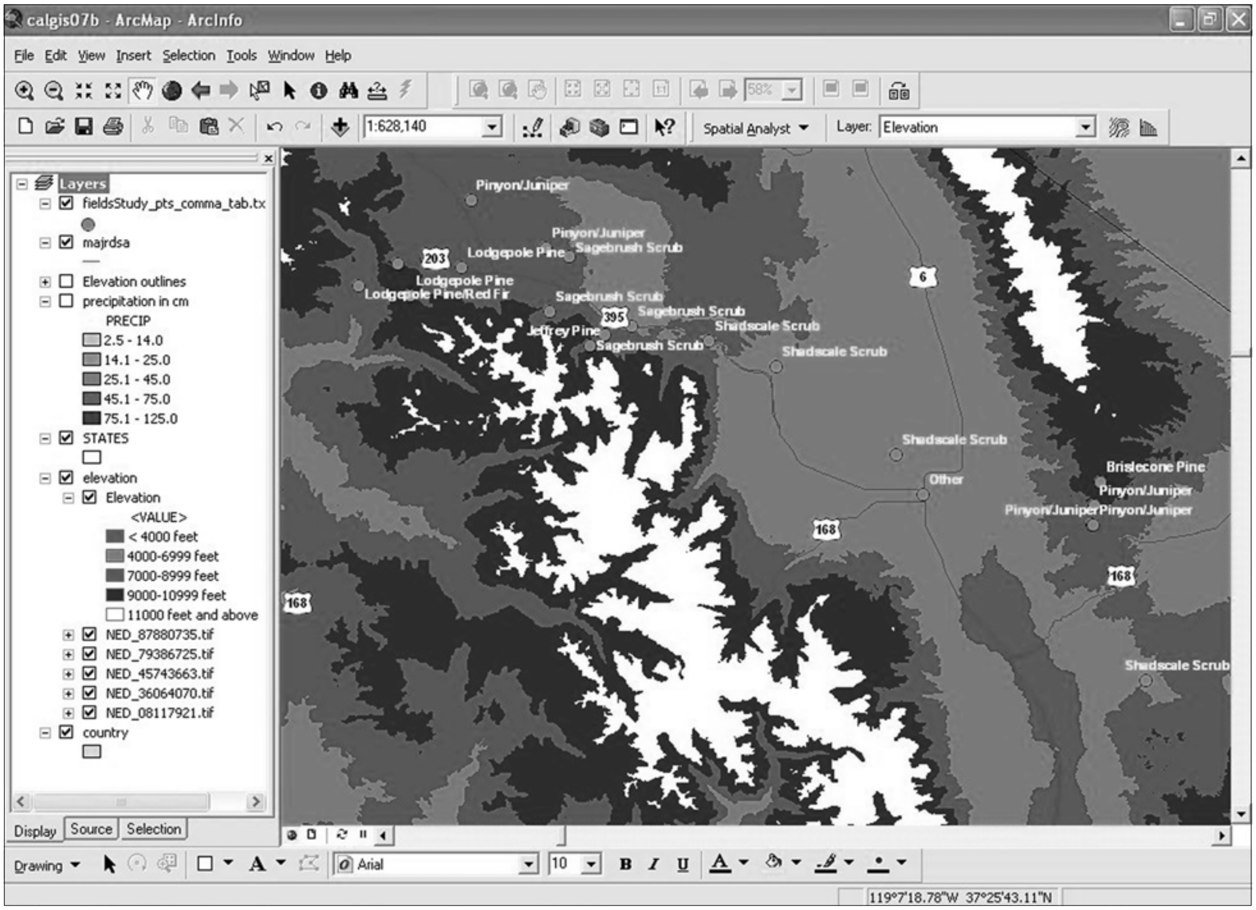

Figure 2. Screenshot of elevation contour map used during ArcGIS presentation with vegetation points added. Students did not have individual computers, so the whole screen was projected.

Pre-activity question

"What differences in vegetation do you predict we will see as we travel throughout the Eastern Sierra Nevada and Western Inyo and White Mountains? Be sure to say why you expect these differences and be as specific as you can."

Student pre-activity response

"Changes in elevation and changes in vegetation as we move up in elevation & from one side of the mountain to another."

Post-activity question

"Now that we have completed the exercise, explain the differences in vegetation throughout the Eastern Sierra and Western Inyo and White Mountains."

Student post-activity response

"The type of vegetation you find is based on the elevation, amount of precipitation, east/west orientation & temperature. Eastern Sierra—high elevation, fur [sic], lodge pine (required more precipitation and cooler temp.) Mid elevation—sage (moderate temperature/precip). Low—creosote/shadscale (warmer temp/lot less precipitation). Western Inyo—high [elevation] (bristlecone pine)."

It should be noted that this response represented the biggest increase in score, and does not represent the highest final score. While most students showed improved knowledge in their post-test answers about the effect of elevation on vegetation, most students did not earn the full 10 points, possibly due to less demonstration of knowledge about the role of aspect. In the future, compass bearings may be taken along with the GPS points to emphasize the importance of aspect.

Because GIS was not used in 2008, the instructors thought it would be prudent to ask the students if they would like more information about how they could use GIS in their classes. A similar question was asked about Google Earth for comparison purposes. All 12 students (100%) agreed that they would like more information about how to incorporate Google Earth into their classroom and 10 out of 12 students (83.3%) wanted more information about GIS. This was

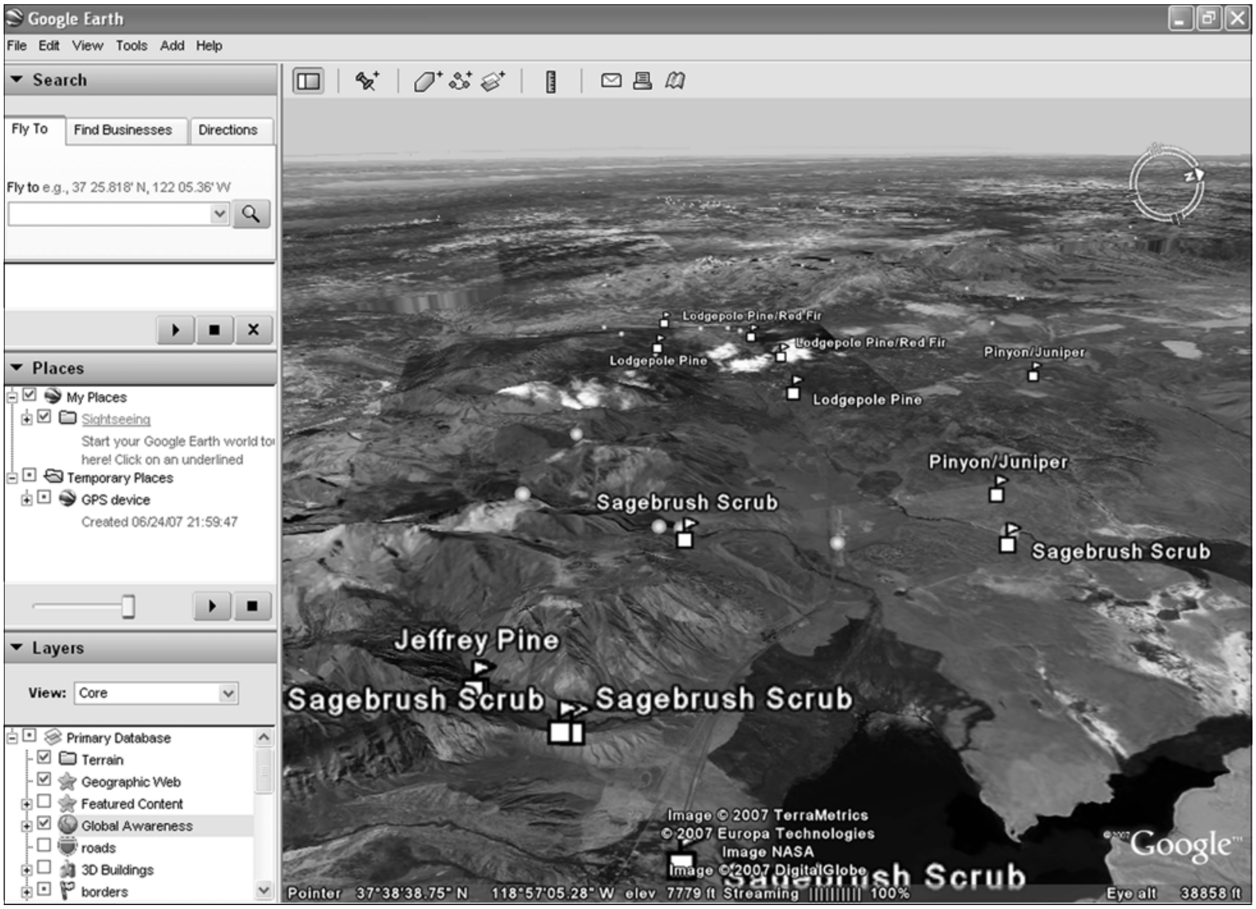

Figure 3. Screenshot from Google Earth showing vegetation points. Students did not have individual computers, so the whole screen was projected .

similar to Settlage et al.'s (2004) discovery in a survey of science educators that even though understanding of GIS and GPS were low (1 on a scale from 1 to 5), desire to learn about them was very high (5 on a scale from 1 to 5).

CONCLUSIONS

It is not clear from the students' written responses whether use of GPS, GIS, or Google Earth alone had the greatest impact on discovering the relationship between elevation, aspect and vegetation in the Sierra Nevada and White and Inyo Mountains. Likely it is a combination of the hands-on nature of recording points with the GPS followed by the GIS/Google Earth presentation.

Several results did emerge from the study. Feedback was very positive on the use of GPS, GIS and Google Earth, and students became comfortable with the GPS units very quickly. Somewhat surprising was the fact that everyone in the 2007 class had used Google Earth before—another reason why it alone was used in 2008. Given that teachers (as represented by this group of science teacher-students) may already be comfortable with Google Earth, this strengthens its possibility to be incorporated into lessons where it can illustrate geoscience concepts.

Besides the concept discussed in this study, alternate projects may involve collecting GPS points along a shoreline or among glacial features and then viewing these features in 3D in Google Earth. Google Earth can even incorporate layers similar to a GIS, although the strengths of a GIS lie in its ability to model multiple layers, and not simply display them. A trade-off has been noted between how much a technology is capable of and it ease of use (Kerski, 2003).

Some concerns voiced by students are the same today as they were ten years ago. GIS involved time for training and resources that was not available (Meyer et al, 1999) — despite Shelley's (1999) prediction that GIS was becoming more common and thus teaching how GIS works would become less important. Kerski estimated in 2003 that GIS had only been adopted by less than 2% of American high schools. Of the students who have attended this field course in the past, it has been typical over the last two to three years for at least one of them to have already used GIS in their classrooms.

Combining GPS with Google Earth or GIS can fulfil several of the National Geography standards, and two of the students indicated they already did or would in the future use GPS to teach about latitude, longitude and mapping (see Geography Education Standards Project, 1994). It also incorporates active, constructivist learning strategies through the collection of the GPS points and the discovery of relationships. This study indicates combining GPS especially with Google Earth is a flexible, cheap and visually potent way to incorporate geospatial technology to teach a number of earth science concepts, including the relationship between elevation and vegetation.

RESOURCES

The authors would like to add that obtaining GIS for use in the K-12 classroom need not be a large expense. Options for incorporating GIS into K-12 education are available on the website of the largest provider of GIS software, Environmental Systems Research Institute (commonly called ESRI).

One option, ArcExplorer Java Edition, is free for educators and can accomplish a number of data exploration goals (http://www.esri.com/industries/k-12/education/software_options.html).

Additionally, the Our World GIS Education series of publications available for purchase contains lesson plans and exercises for grades 3 through 12. Case studies presented on the ESRI website included students' projects about short-horned lizards, active volcanoes and the relocation of a graveyard.

Google Earth is free for download from their website (http://earth.google.com). Like GIS, there are other versions with additional options that can be purchased. Google also maintains a site for educators. Classroom ideas for incorporating Google Earth or Google Maps included topics such as the 2004 Indian Ocean tsunami, global warming, and volcanism (http://www.google.com/educators/geo_class.html).

Readers are encouraged to see Schultz et al. (2008) for a thorough discussion of the applications of virtual globes such as Google Earth, their validity as teaching tools, practical information about the use of Google Earth and examples of how geography standards can be taught using virtual globes.

RECOMMENDATIONS

For teachers at either the K-12 or college level who wish to incorporate a similar exercise on the relationship between elevation and vegetation, the following recommendations would make the activity stronger. A denser network of observations would have made the relationship between vegetation, elevation and aspect easier to spot on either Google Earth or GIS. If the sole purpose of the excursion were to learn about this relationship, a smaller area with a well-defined sampling strategy would have been more appropriate.

Also, the presentation and second part of the activity was completed at night after a day in the field. The activity was completed especially late in the day on the 2008 field course and this may have affected the students' performance on the activity questions. It was evident that the class was tired, and their enthusiasm for the technology was less than in the 2007 class. The lateness of the activity and the tiredness of the students led the instructors to spend less time reviewing all the options available with Google Earth as they had done the year before with both GIS and Google Earth. Therefore, the activity should be planned for a time when students are more alert, and when there is enough time for students to experiment with the technology themselves, the latter suggestion also made by Shin (2006).

Finally, the students may have been more engaged in the 2008 presentation if their complete set of data points had been included rather than a couple points added to the previous class's data.

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