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Learning Geomorphology Using Aerial Photography in a Web-facilitated Class

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Abstract

General education students taking freshman-level physical geography and geomorphology classes at Arizona State University completed an online laboratory whose main tool was Google Earth. Early in the semester, oblique and planimetric views introduced students to a few volcanic, tectonic, glacial, karst, and coastal landforms. Semi-quantitative analysis of student performance compared across prior experience using Google Earth, self-reported learning styles, and math backgrounds revealed no statistically significant correlations. Despite the online nature of the learning experience leading to logistical frustrations such as how to annotate screen captured imagery, qualitative analysis of student feedback agreed with prior similar research on the necessity for: scaffolding; clear learner objectives followed by a sequence of tasks results in superior student learning; and on the observation that students do not benefit from prior schema regarding math training or previous use of Google Earth to perform well. Supplementation with Google Street Views, panoramas, topographic maps, and terrain views enhanced student learning in several ways. First, self-declared kinesthetic learners preferred these supplements over self-declared visual learners. Second, these supplements gave the aerial photo experience more of the feel of a virtual field trip experience, which then aided student learning.

Keywords: aerial photography, Google Earth, landforms, online learning

Introduction

The teaching of landforms has long been a part of the education of a geographer (Davis, 1902; Lobeck, 1924; Raisz, 1931; Sauer, 1956). Using aerial photography remains a universal component of student exercises in learning geomorphology, whether it is through the use of stereopairs (Giardino & Thornhill, 1984) or more recently, Google Earth (Google, 2013) in laboratory manuals (Thomsen & Christopherson, 2010) and other forms of learning (T. R. Allen, 2008; Lisle, 2006). The consensus of a Geological Society of America Penrose Conference in January 2011 (Whitmeyer, Bailey, De Paor, & Ornduff, 2012) held that Google Earth and other virtual visualizations advance both earth science education and research.

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While aerial photography has been a crucial tool and resource to the physical geographer for decades, other forms of visualizations can enhance its value. When meaningfuly arranged, or scaffolded to provide context (Bodzin & Cirucci, 2009), the otherwise foreign language and information-dense nature of aerial photography and imagery becomes more comprehensible and meaningful to the layperson (Appleton & Lovett, 2005) or the student (Kinzel & Wright, 2008). Virtual Field Trips or Virtual Field Experiences (VFTs/VFEs), as part of a structured curriculum or life-long learning, can make use of a variety of geo-visualization technologies and tools to very nearly simulate an actual excursion (Crampton, 2002; Granshaw & Duggan-Haas, 2012; Lang, Lang, & Camodeca, 2012; Stumpf, Douglass, & Dorn, 2008). The realistic feeling that visualizations evoke to supplement and enhance traditional aerial photography is possible largely because of the digital elevation model (DEM). They opened the door to 3D virtual realities (Faust, 1995), photorealistic terrain visualizations (Graf et al., 1994), and digital modelling and mapping (Smith & Clark, 2005; Smith, Rose, & Booth, 2006). In all, the ability to see the earth from multiple perspectives and at multiple scales, with complimentary text, audio, or video media, provides a powerful array of options for geographic learning.

Introductory physical geography courses in the United States are typically general education courses that end up recruiting new geographers into the field (Beck, 1974; Hoisch & Bowie, 2010; Nellis, 1994; Stumpf et al., 2008; Trupe, 2006). As a consequence, students with various preferred learning styles (Bransford, Brown, & Cocking, 2000) from various disciplines—the full spectrum of a university from humanities and the fine arts, business, social science, and natural science end up taking these courses (Hudak, 2003).

Accommodating all students with the best, complimentary instruction is a constant challenge. Online, hybrid, and web-assisted courses alleviate this issue and are a persistent element of the growth of higher education in the United States (I. E. Allen & Seaman, 2005, 2010; Duffy & Kirkley, 2004; Olson, 2013) and globally (Hiltz & Turoff, 2005). In physical geography education, initial research suggests that web-based learning is at least a viable alternative to the traditional classroom (Jain & Getis, 2003).

This paper explores the issue of using Google Earth and various supplemental visualizations to assist the learning of landforms by general education students in an online physical geography laboratory at the largest public university in the USA—Arizona State University (ASU). Over ninety students from more than 30 different majors used different combinations of 360˚ panoramas, helicopter views, Google Street Views, terrain maps, contour maps, and other supplements to assist in the learning of landforms through both planimetric and oblique Google Earth visualizations. After presenting the methods employed to analyze student learning in the next section, both quantitative and qualitative findings reveal the aerial photography viewed in Google Earth assists in student learning — but there exists greater learning potential when students also view these same landforms with other visualizations.

Context and Nature of the Aerial Photo Assignment

Introduction to Physical Geography (GPH111) and *Introduction to Landform Processes* (GPH211) are two first-year courses offered in Geography at ASU. I developed a new online aerial photography laboratory to aid in student learning of landforms in these two courses. The objectives of this lab were for them to 1) learn to use aerial photographs to interpret some basic landforms; 2) learn to use supplemental resources to enhance the power of aerial photos in analysing landforms; and 3) gain confidence in having fun exploring aerial photographs. The lab can be viewed as a static supplemental file: http://alliance.la.asu.edu/aerialphotography/AerialPhotoLab.pdf. Students completed the lab using an innovative grading tool, http://www.gradeify.com/, designed to facilitate such student activities as annotating and uploading screenshots of Google Earth. This lab-hosting tool is also extremely time efficient in providing tailored feedback.

Students completed this aerial photo interpretation lab early in the semester. As such, the tool of aerial photography introduced many of the basic landforms that students would explore later in greater detail. The lab consisted of a series of questions and tasks that introduced students to a resource that would aid them in *seeing* and learning to interpret an aerial view and connect those images to formative processes learned through lectures and readings (Table 1). Each section offered brief explanations in text and diagrams, instructional material and links to supplemental information such as online lectures. This online activity required that students take and submit screen captures of imagery they obtained using Google Earth, and in multiple cases to annotate them with labels and symbols. While taking a screen shot is an intuitive task, the laboratory contained instructions and a chance to practice before encountering the first content questions. Several of the tasks also involved students making calculations such as the volume of sinkholes or uplift rates of marine terraces. Students then shared their thoughts on the value of different Google Earth-visualizations-landform combinations after each task.

The research question of analyzing the power of Google Earth in concert with supplementary visualizations for different types of students is possible only because of the growth of available enhancements to planimetric aerial photography. Other supplemental visualizations include online 360˚ panoramas (http://www.panoramas.dk/US/), helicopter views (http://www.californiacoastline.org/), terrain (shaded 3D topographic) and online topographic maps (http://mapper.acme.com/).

Student Background

In the Spring 2012 semester, 155 students enrolled in ASU's GPH111 or its GPH211 courses — both offered by the School of Geographical Sciences and Urban Planning. Of these, 92 students (evenly split between the two courses) completed the Aerial Photo Interpretation lab as a graded assignment. GPH111 fulfils a quantitative science requirement and thus attracts students from a wide range of majors although it is a required course for geography majors. GPH211 also attracts a wide range of students.

Table 1.
Sequence of Student Tasks in Online Aerial Photo Laboratory

Topic	**Supplemental Visualization(s) used in conjunction with Google Earth Oblique and/or Planimetric Views &** ***Student Question***	**Screenshots**	**Annotations**	**Calculations**
Practice annotating screenshot	None	□	□	
Basalt flow textures	Google Street Views *What do you think about the value of aerial photographs with a planimetric view? Are they interesting to look at? Do you like this perspective? Did it help you to see a ground view of the same location?*	□		
Volcano types and heights	Acme Mapper display of topographic map *What do you think about the value of aerial photographs with an oblique view? Do you like this perspective? Did this perspective help you see the difference between volcano types?*	□		□
Faulting landforms	Planimetric to Oblique (switching) *When you were switching the view from planimetric to oblique, were you able to see the landforms better? Why? or Why not? Please let me know if the process of changing the view affected how you were able to see the landforms*.	□	□	
Glacial landforms	QTVR (360 panoramic view) *I am very interested in whether the ground perspective helped you. Did the panoramic (QTVR) file give you a better feeling for interpreting the landforms you were seeing in Google Earth?*	□	□	
Cuesta landforms	Acme Mapper terrain map / geologic layer overlay and elevation profile view *How well did the terrain view help you 'see' or better understand cuesta landforms? I am wondering if the terrain view, along with aerial photography, helps you see landforms of sedimentary rock.*	□	□	□
Sinkhole volume	Acme Mapper topographic map *I would love to learn your perceptions about how topographic maps and aerial photos work together with making calculations.*	□	□	□
Marine terrace uplift	Helicopter Views / Acme Mapper topographic map *I am interested in learning your thoughts on the interplay of different views of a landform like a marine terrace. Did helicopter views help you understand uplift in the formation of this landform?*			□
Grand Canyon and chosen hike	Virtual hike *I am interested in learning your thoughts about the role of aerial photographs in research that you might carry out on a vacation in your future. Do you plan to use these tools as you plan a future vacation?*	□		

Given an emphasis of quantitative reasoning in this lab, such as estimating the mass lost in sinkhole dissolution, an issue of relevance is the math background of students. Out of the 37 different majors declared by these students, 17 require only the basic college math course (MAT 142), 16 require more extensive mathematics, and the remaining four do not mention a specific math requirement on their department website and/or are a non-degree program. Of the students who completed this lab, 42 have taken or will take math courses higher than basic as part of their degree program while 44 must only complete MAT 142. Although a freshmen-level course, the majority were upperclassmen; 16 freshmen, 22 sophomores, 36 juniors, and 18 seniors.

Methodology

Data Compilation

All student lab submissions were compiled into a spreadsheet, including text answers, screen shots, points awarded to each question, and student's written feedback to post-task questions in Table 1. Student-based input constituted the rows. The complete dataset (large PDF file, 368MB) and a guide are available for review at the following location: http://alliance.la.asu.edu/temporary/PalmerRIGEO/. Student identities are masked with a code (e.g. "Student S24").

Filtering Student Responses to questions: Screen Shot-weighted Scores

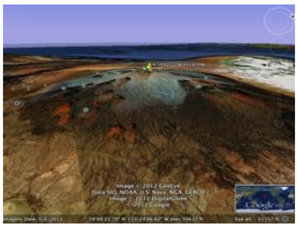
In reading the raw answers to the questions asked about various visualizations, some students provided feedback to please the instructor. This answer bias was detected if a student clearly did not do well on the task, but then explained how much they enjoyed learning about a landform this way. His/her feedback should hold less weight than those students that did well regardless to whether their reaction to a visualization was positive or negative.

An independent score and rank system served to distinguish more authentic, more sincere feedback that was not part of their grade on the lab. The quality of the product (screen shot and annotations) created by each student was ranked on an ordinal scale from 0 to 3 and then summed as a screen shot score (SSS), both for that particular task and for the lab overall (Table 2). Screen shots of landforms that would be useable in a slideshow or lecture in a classroom setting earned a '3'. Those not suitable for the classroom but indicating a decent attempt at following the instructions received a '2'. This ranking was usually the result of being zoomed in too close or out too far, or not being oblique enough to see the landform's profile. A '2' may also indicate the student did not completely grasp the landform even after reading and viewing instructional material prior to examining it in Google Earth. A '1' was assigned to screen shots that were completely unusable, where the landform was not recognizable, and when they revealed the student clearly did not understand the instructions or was confused about the landform or the imagery. Finally, students that did not submit a screen shot received a '0' score for that task. Whenever a student's responses are referenced in this report they are accompanied by their total Lab SSS and, if applicable, their SSS for that particular lab task.

While also serving as a way to weight student feedback, the formulation of the Screen Shot Score (SSS) metric also allows for a quantitative analysis of a student's individual performance. Strong students—those who consistenly viewed, labelled, measured, and experienced (virtually) landforms in Google Earth in the manner intended—could be expected to have a total Lab SSS in the range 33 to 39. Lab SSS for those who's screen shots received more '2s' than '3s', indicating weaker performance, would fall somewhere between 20 to 32 and a combination of primarily '1s' and '0s' at 19 and below.

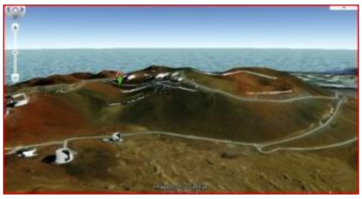
Table 2.

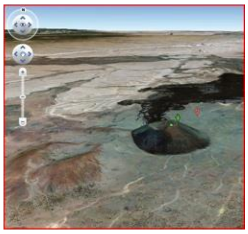
Three students' screen shots identifying basic volcano types and their associated ordinal performance scores (0-3). Because the lab asked for three volcano screen shots, this particular task had a potential maximum score of 9, which could then be used to weight their written feedback. Total Lab SSS possible for the lab is 39 and serves as an overall performance indicator



			SS	**9**
3	**3**	**3**	S	**3**
			Lab	**7**

Student S80: *"I absolutely love looking at the oblique view. They give me an actual feeling of the height of the volcanoes. I think that seeing them as if I were actually in front of them allows me to get a more real feel of the volcanoes."*





			SS	**7**
2	**2**	**3**	S	**2**
			Lab	**3**

Student S122: *"For this particular activity I found the aerial photographs with the oblique views to be very helpful, as well as interesting...these photographs are the next best thing to help me understand the overall shape and features that these specific volcanoes have"*



			SS	**4**
1	**1**	**2**	S	**2**
			Lab	**5**

Student S8: *"I found this perspective to be the most confusing. I am not use to using google earth so it was difficult for me to figure out how to figure out the correct angle for the perspective to be considered oblique. I found it difficult to understand what I was exactly looking at."*

Statistical Methods

This study purposely focused on student feedback and reactions to learning landforms through Google Earth and thus did not incorporate a pre/post-test measurement of learning gains, as is common. Instead, I qualitatively compared categories and groupings of students, and semi-quantitatively compared performance scores (how well they did at producing quality visual images to communicate landforms) against several groups to test their effects. Chi-squares offers a way to compare the many categorical variables of students within the dataset and nonparametric independent-samples Kruskal-Wallis' tests reveal whether a Lab SSS distribution is the same across key variables.

The compiled dataset contains many categorical variables. Student feedback to survey questions throughout the lab enabled grouping and tallying students according to common responses and opinions. For example, after switching between planimetric and oblique perspectives of several faulting landforms, student responses fell into categories such as 'liked switching between planimetric and oblique', 'felt oblique view is sufficient', 'felt planimetric is sufficient', and 'felt negatively about switching'. The final survey question of the lab asked students to reflect on what part of the lab experience helped them the most. From this question, common responses resulted in 14 categorical variables (Table 3) to search trends across the data set.

Table 3.
Common responses to lab survey questions and demographic information

<table>
<tr><td rowspan="2">Most helpful aspects of lab</td><td rowspan="2">•Using aerial photography for the first time to look at landforms
•Using Google Earth
•Oblique Views
•Ground Views (Street View)
•Using ACME Mapper
•Seeing the Landform-process connection
•Using topographic maps
•Annotating Screen Shots
•Using Google Earth's elevation profile feature
•The instructions (text, lectures, diagrams, videos) of the lab
•Making Calculations from aerial photographs and visualizations
•Learning about volcanoes through aerial photography
•Did not like anything in this lab, or did not like this lab overall
•Not Sure</td><td>Self-declared learning style(s)</td><td>•Visual
•Auditory
•Kinesthetic
•Spatial
•Interpersonal
•Intrapersonal
•Naturalistic
•Musical
•Word
•Not Sure</td></tr>
<tr><td>Demographic and other information</td><td>•Math Requirement of declared major (basic vs. advanced)
•Grade level (Freshmen, Sophomore, Junior, Senior)
•Prior time using Google Earth more than / less than reported median value (30 min)
•Reported time spent on lab (how long it took) shorter / longer than median value (6 hours) for population
•GPH 111 vs. GPH 211 student</td></tr>
</table>

Findings

Overall, students responded positively to learning landforms and their associated formative processes using Google Earth and supplementary visualizations. Of the 68 students who gave a response (several students' responses fell into multiple common categories, but usually not more than two) to final feedback question (Table 3), 25 students remarked that they enjoyed their first time interpreting aerial photography. 22 mentioned Google Earth specifically as the most helpful aspect of the lab. Additionally, 11 students felt that being able to see landforms from an oblique perspective made a difference for them. Overal feedback from another 11 students related to positive experiences with grasping the landform-process connection as they viewed aerial photography and supplementary enhancements. Only five of the 68 students left negative comments about an aspect of the lab or about the lab overall. Regarding their overall performance, 33% of students had high total Lab SSSs (33-39), 59% in the medium range, and 8% were lower.

Influence of Prior Experience, Self-Declared Learning Style and Math Background

Although a quick glance at the mean Lab SSS for three groupings—prior use of Google Earth, learning style, and the math requirement of declared majors—suggests they do not assert any significant influence on student performance, this descriptor is essentially a summed ordinal metric that is not normally distributed and, thus, nonparametric tests are best suited to detect significance. I used an independent-samples Kruskal-Wallis' Test to confirm that a group's Lab SSS distribution is not significantly different than another's.

Table 4.
Means and Independent-samples Kruskal-Wallis' Test of Lab SSS across prior experience, self-declared learning style, and math background of students

Category	N	Mean (Std Dev)	(α = 0.05) Asymptotic Sig.
<30 min prior GE use	48	28.60 (6.89)	0.989
≥30 min prior GE use	39	28.88 (6.65)	
Visual learners	42	28.51 (5.82)	0.171
Other learning types	24	30.77 (5.08)	
Major has advanced math requirement	42	29.69 (6.40)	0.263
Major has basic math requirement	44	27.91 (7.25)	

Slightly less than one-third of students reported that they had never used Google Earth before (zero hours of prior use). The median reported time was 30 minutes. The mean Lab SSS for students reporting less than 30 minutes of prior exploration and for those reporting more are nearly identical. Kruskal-Wallis' Test confirms that the overall performance score distribution of these two groups is the same (Table 4).

Although there has been some on-going critique of classifying students as visual learners (Reynolds, 1997; Willingham, 2005), a reasonable position is that aerial photography interpretation would be a highly 'visual' exercise (Hennessy, Arnason, Ratinen, & Rubensdotter, 2012). As part of the final feedback section, students had the opportunity to report the learning style that best describes them by referring to an explanatory diagram that included visual learner as an option. Unexpectedly, the mean SSS for those students who reported a learning type other than visual was higher than those students who identified themselves as visual learners. Although they performed better, Kruskal-Wallis' Test suggests that their Lab SSS distribution is not significantly different from visual learners (Table 4). For this group, students who did not provide a response were not automatically assumed to be 'other learning types' and were not included in the analysis.

Thinking that the math background of a student might influence their ability and comfort level with the numerical tasks, I hypothesized those students selecting majors requiring only one basic math class would not perform as well as those with a stronger math background. Although students who take (or will take) more advanced math courses in college performed slightly better, on average there was no statistically significant difference between the distribution of Lab SSS of the two math groupings (Table 4).

Chi-squares Results Comparing Categorical Variables

Given the many categorical variables available to be compared against each other (Table 3), Pearson's Chi Squares provides a way to see if variations within student responses were due to chance or linked to other factors. At the standard $\alpha = 0.05$ level, Chi Squares revealed several interesting statistically significant relationships. One student sub-group that had a high rate of predictability was the kinesthetic (hands-on) learner group. They were more likely (Prob>ChiSquare = 0.0170) to have the opinion that planimetric aerial photos are not easy to interpret after looking at the color and texture of basalt flows in Hawaii from straight above and from a Google Street View (ground) perspective. After annotating an ACME Mapper terrain visualization (3D shaded contour map) to identify mesas and buttes in Canyonlands near Moab, Utah, kinesthetic learners (0.0487**)** were more likely to remark that they liked the terrain view. Consistent with this, kinesthetic learners (0.0412) were also more likely to say they did not like using traditional topographic maps when used to calculate the volume of dissolved limestone in the McCauley Sinks, AZ. A statistically significant portion of these students (0.0324) remarked positively about helicopter views (large-scale, low-angle oblique sequence of photos) along the California coastline to 'see' rates of uplift. Finally, not by chance, kinesthetic learners (0.0336) stated that the most helpful aspect of this online lab experience was looking at landforms in Google Earth from an oblique perspective.

Another group that had several statistically significant relationships surface in a Chi Squares analysis is self-declared visual learners. Visual learners (0.0230), more than others types, liked the 360° panoramic view of Peyto Lake in the Canadian Rockies to help them see and label glacial features in their self-crafted oblique Google Earth screen capture. Like the kinesthetic group, they were also more likely to comment that they liked the helicopter view enhancement to Google Earth's depiction of the coastline, except the strength of this link (0.0009) was at an order of magnitude higher. Stronger yet, it was not by chance that visual learners were more likely (0.0001) to remark positively about their first exposure to and attempts at interpreting aerial photography.

There were several other statistically significant connections between student responses to the lab's feedback questions and student categories in a Chi Squares analysis of Table 3. Students that reported they had spent more than 30 min (more than the median for the population) using Google Earth prior to this lab were more likely to find the planimetric view of basalt flows in Hawaii easy to interpret (0.0052) and were also more likely to say they only needed the oblique view (vs. switching between planimetric and oblique) to interpret imagery of faulting landforms (0.0401). Students who reported they spent more than 6 hours (median time for population) completing this lab also found useful the supplemental helicopter view of the marine terrace uplift question (0.0294). Students enrolled in *Landform Processes* (GPH211) were more likely to express enthusiasm and excitement in using Google Earth to plan their next vacation or hike than students enrolled in the introductory physical geography class (0.0482). Lastly, students who's major requires only the basic math class more consistently found the planimetric perspectives of basalt flows in the lab's first exercise difficult to interpret (0.0232).

All other possible categorical variable combinations were either not statistically significant or did not have enough data points to give reliable Chi Square scores, but this does not mean that the lack of relationships is not meaningful to this study. I had hypothesized that visual learners, higher prior use, and advanced math requirement majors would, more than others, like using Google Earth to learn landforms, however if any of the students in these categories felt this way I cannot rule out that it was due to chance. I had also suspected that math requirement would be a strong predictor of who would enjoy making calculations of landform processes using Google Earth imagery and visualization tools, but again there were no statistically significant relationships here. GPH 211 students, who were taking a course more focused on landform processes, similarly did not have any connection, surprisingly, with the most helpful aspect of the lab common response category 'seeing the landform-process connection'. Finally, assuming older and more experienced college students may have an advantage over freshmen, I was stumped to see that academic grade level was not a reliable predictor of any common feedback responses in Table 3.

Discussion and Conclusion

Google Earth-based Virtual Field Trips as an Alternative or Supplement to Fieldwork

Researchers emphasize the ability of Google Earth and VFTs to provide a tremendous opportunity for learning (Harper, 2004; Hurst, 1998) without the cost and logistical burden of actual field visits, although nobody is yet advocating that real trips are obsolete; quite the opposite (Fuller, Rawlinson, & Bevan, 2000; Kent, Gilbertson, & Hunt, 1997; Spicer & Stratford, 2001). Students and classrooms are merely a click away from the 'next best' thing to visiting almost anywhere in the world (Tewksbury, Dokmak, Tarabees, & Mansour, 2012). Also, because of their value, many educators are electing to take their classes on virtual field trips before and/or after actual trips to more fully compete and engage the students in the learning process (Johnson et al., 2011; Stumpf et al., 2008). Lang et al. (2012) provides a wonderful synopsis of creating and incorporating VFTs into an introductory geology course where students' learning gains were measured and compared against the traditional lecture format. While their results were not statistically significant, students who were exposed to a VFT of volcanism in Tenerife, Spain performed better, on average, when comparing pre/post tests of the two groups. The authors mention that their study indicates that

> *...student learning [was] positively impacted with this VFT. This is further supported by student surveys and informal interviews conducted after each study…[M]ultiple students mentioned a preference to hands-on type learning experiences such as this VFT over traditional in class teaching approaches such as lecturing (pg 332).*

While this report's aerial photo interpretation lab was not set up intentionally as a VFT, it shares many similar characteristicas and many of the participant's remarks indicate that they felt as if they were really visiting and observing these landforms in person. This is due to the combination of location visits in Google Earth enhanced with supplemental visualizations, the scaffolding background material provided in each section, and their active interaction with the subject by crafting views, annotating, and measuring. Referring to the power of an oblique view to see volcanoes Student S52 (SSS 9/9, Lab SSS 27) said, "…I think they are interesting to look at it because it is kind of like seeing it in person however you are not really there...It's more realistic to look at things like this (even still on the computer) than just regular aerial like a bird…I thought it was really cool and helpful to see the volcanoes so realistically." Actual field trips for GPH111 and 211 students to Mt. Hood, SP Crater, and Mauna Kea were not an option, but they were able to visit these and other landforms virtually via Google Earth. Similarly, these students would be better prepared for a day of field work and research to, for instance, McCauley Sinks, Arizona, just a few hours north of campus because of having already familiarized themselves through interpreting aerial photography and from making calculations from their own measurements from a topographic map.

Perception of Learning and Enjoyement Enhanced When Students Are Offered More Than One Perspective

Research on landforms being presented via multiple perspectives when learning landforms reveals an enhancement of student learning (Hagevik & Watson, 2003; Liu & Zhu, 2008). Multiple perspectives can mean the examination of landforms from different angles, as is possible with Google Earth, or it can more broadly refer to the presentation of supplemental material that offers additional perspectives of a subject or landform. Krzic et al. (2012) reports an online teaching tool called SoilWeb that provides students with a web-based, interactive, 'at-their-own-pace' venue of video and audio recordings, photos, text, and graphics to help place landforms into their geomorphic contexts only to be surpassed by extended visits to the field. Responses from students about SoilWeb were positive and encouraging. Another key study, Johnson et al. (2011), featured student responses to provide insight on how they were learning in the virtual environment, of which Google Earth and multiple perspectives of landforms was a major component. Once some of the frustrations of using a new program were resolved, positive comments like the two below reveal that students benefited and enjoyed seeing land features from multiple perspectives.

> *"It makes it easier because you're actually [visualizing] stuff, like real stuff. A topography map has mountains and that's nice, but you actually see real features [on Google Earth], an old flood [plain] and bits of deposits. You can't see that on maps.*
>
> *"It was best when we were looking at beaches cause you could turn it onto its side and work out how steep the geography behind it was instead of looking straight down on it (pg 506).*

These prior findings among student comments are reflected in this online aerial photo lab. After the California coastline portion of the lab, Student S22 (Lab SSS = 20) remarked that he/she "…always like[s] the incorporation of other types of images and presentations to see other angles of the landforms. This one in particular was helpful because it felt like I was right there above the landform seeing it from a helicopter." Able to adjust the angle of the Google Earth viewer to one that best fits the faulting landforms, Student S4 (SSS 8/9, Lab SSS = 37) reacted this way:

> *"I was able to see the landforms much more clearly at the oblique angle, this was especially apparent with the Dez River as I didn't easily notice the uplifted portion with the top-down view. However, the view of the San Andreas fault wasn't made any more clear (but it did provide an interesting point of view). Overall changing the view helped quite a bit as it generally added more clarity to the shape and composition of the landforms."*

The ability to manipulate, move, swivel, tilt the view in Google Earth, and to compare these views with supplemental visualizations is almost like handing a plaster model of these landforms to the students for them to touch and handle for themselves. It became apparent, however, that learning is enhanced only to the degree students can read, understand, or interpret the supplemental and alternative representations. Although they thought the helicopter views were useful because "…they just gave a more in depth angle for anyone to see what [the coastline] actually looked like from multiple sides", Student 65 (Lab SSS = 32), for instance, reported having difficulty reading the contours and elevation data of ACME Mapper's Topographic view of the coastline, which was necessary for calculating uplift rate. Thus one major challenge in an online setting is how to efficiently instruct students to make sense of all the information and tools available to them on the screen.

Active, Hands-On Participation and Creation Fosters Learning and Ownership

The relevance of student-created products appears in a number of papers (Heyl, 1984; Jones & Willis, 2011; Kearney & Schuck, 2005; Manfra & Hammond, 2008; Wake & Wasson, 2011). In essence, this aerial photography lab offered students over a dozen opportunities to craft and annotate screenshots representative of their aerial photography interpretation efforts. Recently, Eusden, Duvall, and Bryant (2012) presented findings from using of Google Earth 'mashups' in an introductory geoglogy class where students reflected and reported on a field trip to the Presidential Range, NH. Utilizing it's native

Keyhole Markup Language (KML), students attached self or group-authored descriptions (text), photos, and YouTube videos to Placemarks (waypoints) in Google Earth of the places they visited on their trip. These mashups embodied the creative reflection of what they experienced and learned in the field in a manner familiar to social networking and have the advantage of being easily shared and downloaded among the class or the entire world online. These researchers report that this project was very successful, effective, and fun for all involved and that "…student feedback on course evaluations was very positive about this experience (pg 363)." This is likely because both the trip and post-trip activities were very 'hands-on', dynamic, and fun; promoting learning beyond the bounds of a formal class structure.

While the lab featured in this study did not involve 'mashups', it was a short step away by having students create a path (as a .kmz file) in Google Earth of their favorite hike (or of some place they would like to visit or hike), take a screenshot, and then breifly describe the geomorphology they see as they experience their hike virtually. Many students seemed to struggle with this as the intellectual leap perhaps was too great or because by this point in the lab they were mentally exhausted as evidenced by their simplistic answers (see Student S76), but the screenshots and descriptions provided by several students (see Students S61 & S105, Table 8) highlight how this type of activity has rich potential to enhance learning as it, in my opinion, more meaningfully links newly acquired skills and knowledge with real experiences, positive emotions, and generates a higher degree of student 'ownership'.

Table 7.

Student screen shots of their chosen hike—represented as a colored path (line)—and their accompanying descriptions of the geomorphology they see

Student S105: *This is the Squaw Peak, and its cooresponding trail, marked in red. This is a very famous mountain in the metro-Phoenix area...I have hiked this trail many times and it gives an amazing perspective of the valley. For this assignment I want to focus on the water channels marked in blue. In this picture you can clearly see how water erosion has formed channels in the side of Squaw Peak and its surrounding mountains. These channels allow water to flow off the mountain in times of rain.* (SSS 5.5/6, Lab SSS 35)	
Student S61: *While I live in Arizona I still haven't seen Meteor Crater. I think I heard that it's not open to the public to hike, but I'd at least like to see it sometime soon, and I can always imagine. Obviously, [it] was formed by a sort of large meteor impact a while back and what we see is the resultant crater. The impact happened recently enough that geological processes have not yet had time to erase it from the landscape and so it's more striking than other, older meteorite impacts. It's just that, stuff from space is so cool.* (SSS 6/6, Lab SSS 38.5)	

Similar to the learning that continued post-trip by Eusden et al. (2012) having their students compile their experiences and knowledge into Google Earth mashups, this lab, because of being web-based and time-efficient to grade, offered a way for learning to extend beyond pressing the ‘submit lab’ button. For instance, because Student S105 (Table 7) described and annotated the erosion-formed channels he had seen in person while hiking and was now interpreting from GE aerial photography of Piestewa Peak in Phoenix, Arizona, the grader—a professor who is an expert on the geomorphological processes of stream base-level adjustment in arid environments—was able to offer this student more tidbits about the landform-process connection:

> “*This part of the Phoenix Mountains is pretty neat. I agree. And **your channels** are a great example of how streams adjust to base level change. Let me back up and explain. All of the streams in metro-Phoenix end up at the Salt River. The Salt River is the base level for all of our ephemeral washes, like your blue lines. So when the Salt River "cuts down", all of the tributary washes also cut down. The Salt River was at the level of ASU's Tempe Campus. Then, about 480,000 years ago it cut down to its present position. **Your blue channels** responded by incising, making narrow mini gorges on the south side. But if **you** look at the channels on the north side of the Phoenix Mountains here, they are not as deeply incised. This is because the streams go all the way around Dreamy Draw before they get to the Salt River. The longer the stream length, the more gentle the adjustment. I hope this makes sense. This would be a great undergraduate research project, a perfect thesis.” (emphasis added)*

It is encouraging to see how a student’s self-created product—their annotated Google Earth screen—enriches and continues the learning process. This kind of positive interaction is surely to spawn more interest and future motivated scientists in the field.

Online learning

Learning about landforms online through Google Earth, with all its potential, has many aspects that need thoughtful consideration. Lang et al. (2012) said that while VFTs, which must be web-based by nature, increased learning, many students mentioned that they would not have been able to do as well without at least some preparation. “Multiple students indicated that without a lecture they likely would have been lost in conducting assignments on [the] VFT (pg 332).” Gobert, Wild, and Rossi (2012) clarifies a possible reason why: “[t]his is likely because students, unlike experts, typically do not know what is salient within rich information sources such as Google Earth, and thus, if unscaffolded (i.e., unguided) they might not acquire the targeted information as intended (pg 466).” Online learning and VFT-centered assignments must be carefully “structured to support students’ learning processes” (pg 466).

Students in the landform processes and introductory physical geography classes did have a lecture component, but not necessarily in direct preparation for this trial lab and thus the it was structured to stand alone. It presented them with clear objectives, an appropriate amount of background material (some of which were pre-recorded lectures), and step-by-step instructions to guide them. Several students in this lab indicated that this scaffolding was crucial to their performance. Even though earlier he/she had expressed frustration after trying to craft an oblique view (this may not have been a problem in a traditional classroom/lab setting with a TA or helpful peers), Student S8 (Lab SSS 25) remarked: "I liked that the instructions were clear and precise so there wasn't much confusion while trying to figure out these tools or how to complete the assignment." Being accessed entirely online, students used any number of different personal computers or laptops at various levels functionality, with various levels of Internet connectivity, and in different settings (at home, the library, or a common computer lab) to complete this lab. As an attempt to look at how students learn landforms in an online setting, further improving the 'structure' and orienting tasks for future students that complete this lab may well result in more apparent and measurable learning gains.

Learner-Centered Exercises

Real learning happens more often when it is made meaningful to the student (Lombardi, 2007) and educators continue to discover and share new and effective ways to use Google Earth for learning (Richard, 2009). This not only improves geoscience teaching strategies but also simultaneously promotes the broader pedagogical shift to learner-centered education practices. VFTs, mahsups, and web-based lab exercises that harness geo-browsers are inherently student-focused. The traditional classroom structure and its formal content/instructor-centered format—where the default is passive absorption of information via lecture—is being replaced with more effective methods. Bailey, Whitmeyer, and De Paor (2012) argue that there is a prominent place for Google Earth and virtual visualizations in geoscience education, but admits that we must first see more evidence of this through in-depth, quantitative research of its influence on learning. This type of research will help us overcome obstacles within academia more than an appeal to the capabilities and potential of these technologies alone. When the numbers confirm what our true customers—the student—are already thinking and saying about learning-focused approaches, the shift is likely to pick up momentum. Both the qualitative and semi-quantitative findings here seem to suggest that learning landforms through Google Earth imagery and media-rich enhancements, when adequately scaffolded, is both enjoyable and effective.

Conclusion

An online aerial photo lab introduced general education students at Arizona State University to landforms in freshman-level physical geography and geomorphology classes. Students from 38 different majors employed planimetric and oblique Google Earth views to explore basic landforms: basalt flow textures supplemented with Google Street Views; volcano types with heights measured through online topographic maps; faulting landforms through annotating landforms like wineglass valleys; glacial landforms supplemented with a 360˚ panorama; cuesta sandstone landforms supplemented by the terrain view, geology layer and elevation profiles; sinkhole volumes supplemented with topographic maps; marine terrace uplift rates supplemented with helicopter photography; and virtual hikes of the Grand Canyon and a student selected location. Data from student responses facilitated the development of a matrix of

92 rows (students) and 74 columns that contained such data as student responses, annotated screenshots, and calculations for categories of student learning.

A mix of quantitative analysis and qualitative observations of student work products, responses, and feedback tend to support some fundamental observations made in prior research. Google Earth as a learning tool in an online lab was received positively by the majority of students and does not seem to favor one particular group based on math background, learning style, or prior experience with the program. New insight from analyses of general education students reveals that Google Earth exercises with supplemental enhancements can feel like a 'hands-on' exercise even though it is really only virtual, are highly visual experiences, and that an emotional connection with a location or landform allows for learning that exceeds the basic objectives.

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References

Allen, I. E., & Seaman, J. (2005). Growing by degrees: online education in the United States, 2005: Sloan Consortium.

Allen, I. E., & Seaman, J. (2010). Learning on Demand: Online Education in the United States, 2009: Sloan Consortium.

Allen, T. R. (2008). Digital Terrain Visualization and Virtual Globes for Teaching Geomorphology. *Journal of Geography, 106*(6), 253-266. doi: 10.1080/00221340701863766

Appleton, K., & Lovett, A. (2005). GIS-based visualisation of development proposals: reactions from planning and related professionals. *Computers, Environment and Urban Systems, 29*(3), 321-339. doi: http://dx.doi.org/10.1016/j.compenvurbsys.2004.05.005

Bailey, J. E., Whitmeyer, S. J., & De Paor, D. G. (2012). Introduction: The application of Google Geo Tools to geoscience education and research. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virtual Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. vii-xix): Geological Society of America.

Beck, A. D. (1974). Geography in the American Community College. *Geography, 59*(4), 333-335. doi: 10.2307/40568289

Bodzin, A. M., & Cirucci, L. (2009). Integrating Geospatial Technologies to Examine Urban Land Use Change: A Design Partnership. *Journal of Geography, 108*(4-5), 186-197.

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experience, and School - Expanded Edition*: National Academies Press

Crampton, J. W. (2002). Interactivity Types in Geographic Visualization. *Cartography and Geographic Information Science, 29*(2), 85-98. doi: 10.1559/152304002782053314

Davis, W. M. (1902). Field Work in Physical Geography. *Journal of Geography, 1*, 17.

Duffy, T. M., & Kirkley, J. R. (2004). *Learner-centered theory and practice in distance education cases from higher education*. Retrieved from http://books.google.com/books?id=ofvrszKV-zsC&lpg=PP1&pg=PP1 - v=onepage&q&f=false.

Eusden, J. D., Duvall, M., & Bryant, M. (2012). Google Earth mashup of the geology in the Presidential Range, New Hampshire: Linking real and virtual field trips for an introductory geology class. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virtual Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 355-366): Geological Society of America

Faust, N. L. (1995). The virtual reality of GIS. *Environment and Planning B: Planning and Design, 22*(3), 257-268.

Fuller, I., Rawlinson, S., & Bevan, R. (2000). Evaluation of Student Learning Experiences in Physical Geography Fieldwork: Paddling or pedagogy? *Journal of Geography in Higher Education, 24*(2), 199-215. doi: 10.1080/713677388

Giardino, J. R., & Thornhill, A. G. (1984). An Evaluation of the Effectiveness of Stereo Slides in Teaching Geomorphology. *Journal of Geological Education, 32*(1), 14-16.

Gobert, J., Wild, S. C., & Rossi, L. (2012). Testing the effects of prior coursework and gender on geoscience learning with Google Earth. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virutal Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 453-468): Geological Society of America.

Google. (2013). Google Earth. Retrieved from http://www.google.com/earth/index.html

Graf, K. C., Suter, M., Hagger, J., Meier, E., Meuret, P., & Nüesch, D. (1994). Perspective terrain visualization—A fusion of remote sensing, GIS, and computer graphics. *Computers & Graphics, 18*(6), 795-802. doi: http://dx.doi.org/10.1016/0097-8493(94)90005-1

Granshaw, F. D., & Duggan-Haas, D. (2012). Virtual fieldwork in geoscience teacher education: Issues, techniques, and models. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virutal Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 285-303): Geologic Society of America.

Hagevik, R., & Watson, M. (2003). *Enhancing Spatial Cognition Using Mapping Technologies in Earth Science Education.* Paper presented at the AGU Fall Meeting Abstracts.

Harper, S. B. (2004). *Geologic Photo Field Trips to View Rocks, Geologic Structures, and Landforms in Introductory Physical Goelogy.* Paper presented at the Geologic Society of America 2004 Denver Annual Meeting.

Hennessy, R., Arnason, T., Ratinen, I., & Rubensdotter, L. (2012). Google Earth geo-education resources: A transnational approach from Ireland, Iceland, Finland, and Norway. In S. J.

Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virtual Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 413-418): Geological Society of America.

Heyl, R. J. (1984). Teaching Landforms in Miniature. *Journal of Geography, 83*(4), 175-176. doi: 10.1080/00221348408980497

Hiltz, S. R., & Turoff, M. (2005). Education goes digital: the evolution of online learning and the revolution in higher education. *Commun. ACM, 48*(10), 59-64. doi: 10.1145/1089107.1089139

Hoisch, T. D., & Bowie, J. I. (2010). Assessing Factors that Influence the Recruitment of Majors from Introductory Geology Classes at Northern Arizona University. *Journal of Geoscience Education, 58*(3), 166-176. doi: 10.5408/1.3544297

Hudak, P. E. (2003). Campus field exercises for introductory geoscience courses. *Journal of Geography, 102*(5), 220-225.

Hurst, S. D. (1998). Use of "virtual" field trips in teaching introductory geology. *Computers & Geosciences, 24*(7), 653-658. doi: http://dx.doi.org/10.1016/S0098-3004(98)00043-0

Jain, C., & Getis, A. (2003). The Effectiveness of Internet-based Instruction: An experiment in physical geography. *Journal of Geography in Higher Education, 27*(2), 153-167. doi: 10.1080/03098260305679

Johnson, E. M., Cowie, B., De Lange, W., Falloon, G., Hight, C., & Khoo, E. (2011). Adoption of innovative e-learning support for teaching: A multiple case study at the University of Waikato. *Australasian Journal of Educational Technology, 27*(3), 499-513.

Jones, C., & Willis, M. (2011). Experience-Based Learning Using Smartphones: The Explorer Project. *International Journal on Human-Computer Interaction 2*(7), 1-20.

Kearney, M., & Schuck, S. (2005). *Students in the Director's Seat: Teaching and Learning with Student-generated Video*. Paper presented at the World Conference on Educational Multimedia, Hypermedia and Telecommunications 2005, Montreal, Canada. http://www.editlib.org/p/20518

Kent, M., Gilbertson, D. D., & Hunt, C. O. (1997). Fieldwork in geography teaching: A critical review of the literature and approaches. *Journal of Geography in Higher Education, 21*(3), 313-332. doi: 10.1080/03098269708725439

Kinzel, M., & Wright, D. (2008). *Using Geovisualizations in the Curriculum: Do Multimedia Tools Enhance Geography Education?* Paper presented at the Environmental Systems Research Institute Education User's Conference.

Krzic, M., Watson, K., Grand, S., Crowley, C., Dyanatkar, S., Bomke, A., & Smith, S. (2012). *From the Field to the Classroom: A Web-Based Teaching Tool on Depositional Environments and Landscape Development.* Paper presented at the EGU General Assembly Conference.

Lang, N. P., Lang, K. T., & Camodeca, B. M. (2012). A geology-focused virtual field trip to Tenerife, Spain. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virtual Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 323-334): Geological Society of America.

Lisle, R. J. (2006). Google Earth: a new geological resource. *Geology Today, 22*(1), 29-32. doi: 10.1111/j.1365-2451.2006.00546.x

Liu, S., & Zhu, X. (2008). Designing a Structured and Interactive Learning Environment Based on GIS for Secondary Geography Education. *Journal of Geography, 107*(1), 12-19. doi: 10.1080/00221340801944425

Lobeck, A. K. (1924). *Block Diagrams and Other Graphic Methods Used in Geology and Geography*: J. Wiley.

Lombardi, M. M. (2007). Authentic learning for the 21st century: An overview (Vol. 1, pp. 1-12): Educause Learning Initiative.

Manfra, M. M., & Hammond, T. C. (2008). Teachers' instructional choices with student-created digital documentaries: Case studies. *Journal of Research on Computing in Education, 41*(2), 223.

Nellis, M. D. (1994). Technology in Geographic Education: Reflections and Future Directions. *Journal of Geography, 93*(1), 36-39. doi: 10.1080/00221349408979683

Olson, S. (Ed.). (2013). *Educating Engineers: Preparing 21st Century Leaders in the Context of New Modes of Learning: Summary of a Forum*: The National Academies Press.

Raisz, E. J. (1931). The Physiographic Method of Representing Scenery on Maps. *Geographical Review, 21*(2), 297-304. doi: 10.2307/209281

Reynolds, M. (1997). Learning Styles: A Critique. *Management Learning, 28*(2), 115-133. doi: 10.1177/1350507697282002

Richard, G. A. (2009). Teaching with Google Earth. *Pedagogy in Action: the SERC portal for Educators* Retrieved 22 March 2013, from http://serc.carleton.edu/sp/library /google_earth/index.html

Sauer, C. O. (1956). The Education of a Geographer. *Annals of the Association of American Geographers, 46*(3), 287-299. doi: 10.1111/j.1467-8306.1956.tb01510.x

Smith, M. J., & Clark, C. D. (2005). Methods for the visualization of digital elevation models for landform mapping. *Earth Surface Processes and Landforms, 30*(7), 885-900. doi: 10.1002/esp.1210

Smith, M. J., Rose, J., & Booth, S. (2006). Geomorphological mapping of glacial landforms from remotely sensed data: An evaluation of the principal data sources and an assessment of their quality. *Geomorphology, 76*(1-2), 148-165.

Spicer, J. I., & Stratford, J. (2001). Student perceptions of a virtual field trip to replace a real field trip. *Journal of Computer Assisted Learning, 17*(4), 345.

Stumpf, R. J., Douglass, J., & Dorn, R. I. (2008). Learning Desert Geomorphology Virtually versus in the Field. *Journal of Geography in Higher Education, 32*(3), 387-399. doi: 10.1080/03098260802221140

Tewksbury, B. J., Dokmak, A. A. K., Tarabees, E. A., & Mansour, A. S. (2012). Google Earth and geologic research in remote regions of the developing world: An example from the Western Desert of Egypt. In S. J. Whitmeyer, J. E. Bailey, D. G. De Paor & T. Ornduff (Eds.), *Google Earth and Virutal Visualizations in Geoscience Education and Research* (Vol. Special Paper 492, pp. 23-36): Geologic Society of America.

Thomsen, C., & Christopherson, R. (2010). *Encounter Geosystems: Interactive Explorations of Earth Using Google Earth*. New York: Prentice Hall.

Trupe, C. H. (2006). *Attracting majors through recruitment talks in introductory geoscience classes.* Paper presented at the 2006 Philadelphia Annual Meeting.

Wake, J. D., & Wasson, B. (2011). *Supporting creativity in teaching and learning of history through small-group production of mobile, location-based games*. Paper presented at the 10th World Conference on Mobile and Contextual Learning, Beijing, China.

Whitmeyer, S. J., Bailey, J. E., De Paor, D. G., & Ornduff, T. (Eds.). (2012). *Google Earth and Virutal Visualizations in Geoscience Education and Research* (Vol. Special Paper 492): Geological Society of America.

Willingham, D. T. (2005). Do visual, auditory, and kinesthetic learners need visual, auditory, and kinesthetic instruction. *American Educator, 29*(2), 31-35.