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Learning Desert Geomorphology Virtually versus in the Field

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ABSTRACT *Statistical analyses of pre-test and post-test results, as well as qualitative insight obtained by essays, compared introductory physical geography college students who learned desert geomorphology only virtually, in the field and both ways. With the exception of establishing geographic context, the virtual field trip was statistically indistinguishable from real field trips in establishing basic knowledge about desert geomorphology. However, qualitative results reveal the deepest personal ownership of knowledge among field trip participants. These findings should not be construed as having validity beyond an introductory course.*

KEY WORDS: Education, fieldwork, geomorphology, physical geography, virtual

Introduction

Advances in computer technology over the past few decades have increased communication formats and multimedia tools, permitting the development of virtual field trips. As class sizes increase and in conjunction with the development of these new technologies, a large number of educational institutions are turning towards the Internet to provide distance-learning opportunities (e.g. WinklerPrins *et al.*, 2007). Geography's acceptance of the Internet as a powerful learning tool (cf. Hill & Solem, 1999) continues to support the power of E-learning in promoting geographic learning (Orion & Hofstein, 1994; Warburton & Higgitt, 1997, Stainfield *et al.*, 2000; Spicer & Stratford, 2001; Robertson & Fluck, 2004; Fletcher *et al.*, 2007; Lynch *et al.*, 2008). As pre-college students continue to receive increased exposure in educational e-Science, new college students are increasingly comfortable learning science virtually (Underwood *et al.*, 2008). Earth and environmental science courses in disciplines related to physical geography continue to explore virtual field experiences (e.g. Ramasundaram *et al.*, 2005). This study, thus, explores the effectiveness of virtual field trips as teaching tools for large classes in physical geography with break-out laboratory sections. We compare student performance for a desert geomorphology module addressed virtually and taught through physical visits to the field.

Readers should understand that all authors have a strong bias in favour of educating students in the field, as opposed to virtual Internet trips. We developed the 'module'

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tested in this study as a part of an entire introductory geomorphology course. The course utilized six virtual field trips with the goal of providing physically disabled students access (cf. Hall *et al.*, 2004) to learner-centred education about south-western landscapes.

Our original bias relates to barriers that limit the effectiveness of virtual learning. Virtual field trips, for example, do not provide the same sensory experiences. Gress and Scott (1996) stress the importance of appealing to the five senses in field-trip simulations. Krygier *et al.* (1997) establish that visual and audio capabilities of multimedia in geographic education provide almost the same sensory experiences as actual field trips via pictures, audio clips and videos. Virtual learning, however, cannot emulate smell or touch. Touch allows physical geography students to experience the mass of rocks, detect texture of soils, or feel waxy coatings of *Larrea tridentata* (creosote bush) leaves that inhibit evaporatranspiration. Smell also assists students in identifying Larrea tridentata by its distinctive odour. The experience of walking over a colluvial-covered desert slope remains entirely different from analysing a visual image. In virtual learning, students must read about these concepts and imagine what their sense of touch, smell and physical effort would provide.

Our bias also resulted from a belief that fieldwork facilitates a greater level of mentoring and interaction between students and instructors (Haffernan *et al.*, 2002), in addition to encouraging teamwork, cooperation and camaraderie that comes from sharing hardship. Virtual learning provides guided instruction but often lacks the interactive and mutual interrogation of place and process by professor and student that occurs in fieldwork. Email and discussion threads do provide interactive opportunities, but they can be impersonal and create miscommunication without the expression of emotion in vocal tone and facial expressions—potentially increasing frustration, and thus detracting from the educational experience.

Several studies conclude that virtual learning greatly improves field experiences when use as a preparatory tool, but should not replace field trips (Orion & Hofstein, 1994; Warburton & Higgitt, 1997; Stainfield *et al.*, 2000; Spicer & Stratford, 2001). These authors argue that virtual field trips and instruction prior to fieldwork allow students to focus on key concepts and use time more efficiently. They do not encourage the replacement of physical fieldwork with virtual field trips because of perceived differences in the experiences. Regardless of our initial views of the superiority of real field trips, it is important to evaluate whether virtual learning is an effective teaching tool in different aspects of geography, because of its current independent use in distance-learning programmes, as well as the need to include physically challenged students in the educational process (cf. Hall *et al.*, 2004).

Students have diverse educational backgrounds and hobbies. The typical, current undergraduate student has grown up with technologies such as video games and the Internet. Are they more aptly equipped to learn better using virtual technologies than students who did not grow up with these experiences? Do students who enjoy playing video games learn better virtually? Do people who like to hike perform better by learning in the field? These are some of the questions this study strives to answer in comparing the performance of students with different interests learning desert geomorphology virtually as opposed to in the field.

We start out with an overview of the field trip locale, explaining why the site exemplifies asymmetry in desert physical geography systems. After detailing methods used in the experiment, we present results that we admit disappointed the author-advocates of real field trips. The discussion then turns on the implications of our findings for the place of virtual field trips in large physical geography courses.

The Site

Tempe Butte (Figure 1), commonly called ‘A Mountain’ because of the large ‘A’ built on a southern slope facing campus, is a city park at the interface of Arizona State University and Downtown Tempe, Arizona. A number of natural science programmes, including anthropology, biological sciences, geological sciences and geography, use the site for student field experiences due to close proximity to campus and a desert environment within an urban setting. The large physical geography introductory labs use Tempe Butte because it provides dramatic differences in south and north exposures of landforms, hydrology, biogeography, soils and geology.

Tempe Butte exhibits asymmetry in geology that leads to asymmetry in landforms. Detachment faulting off of a metamorphic core complex several million years ago tilted a suite of igneous and sedimentary rocks, leaving a layer of andesite on Tempe Butte’s south-facing slope, very different from the predominantly sandstone and shale strata

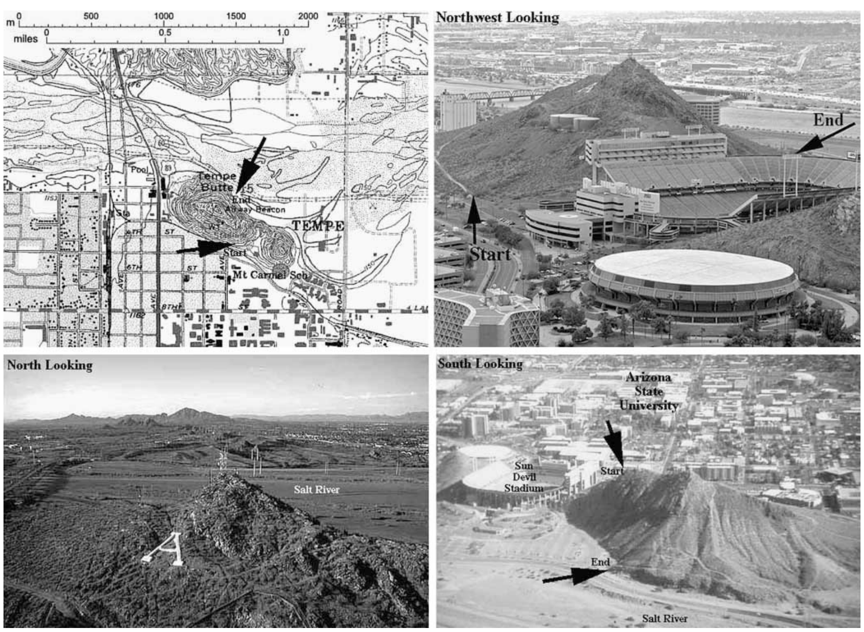

Figure 1. Aerial photographs and topographic map of Tempe Butte providing the overall context of the field trip site. The upper topographic map and right-hand aerial photographs identify the starting and ending points of the field trip. The lower oblique images provide the reader with a sense of the asymmetry: north side sedimentary rocks destabilized by a pre-channelized Salt River; and south side extrusive igneous rock leading to extremely stable slopes. The upper right and lower left images are courtesy of Arizona State University. The full, virtual field trip can be accessed at http://alliance.la.asu.edu/gph111/Virtual/TempeButte/intro/overview.html.

exposed on the northern slope. The combination of a stable base level of a half-million-year old stream terrace and resistant andesite rock resulted in the build-up of a world-class calcrete duricrust in south-side soils. In contrast, relatively friable sandstone and shale, as well as a pre-channelized active Salt River channel, leads to a much less stable north-facing slope with almost no calcrete formation, smaller colluvium and abundant large alluvial cobbles deposited by the Salt River.

Geomorphic asymmetry links to biogeographic contrasts. Xerophyte succulents such as barrel cactus (*Ferocactus wislizenii*) and varieties of cholla (*Opuntia* spp.) species thrive amongst andesite colluvium that develops a dark enough rock varnish to absorb insolation, increasing temperatures and evapotranspiration. Some northern exposures undercut by the Salt River, in contrast, are steep enough to avoid direct insolation, contributing to lower temperatures, less evapotranspiration, and fostering growth of epilithic organisms such as lichens and even moss.

Part of the geomorphic asymmetry comes from human disturbances. The geomorphically stable south side naturally results in andesite surfaces blackened with rock varnish and soils with calcrete. Any rock disturbance on the south side creates dramatic brightening of the landscape from light grey unvarnished andesite, while soil disturbances expose white cement-like calcrete. In contrast, disturbances on the north side are much more difficult to detect, since the sandstone and shale erode too fast naturally to develop noticeable varnish or calcrete. Students see disturbance carved everywhere into natural landforms in features ranging from prehistoric petroglyphs to talus dynamited from modern water tower construction.

The field trip connects to the main lecture of the class in that the virtual/field experience reinforces basic physical geography concepts presented prior to the field trip in lecture of rock type, tilting, weathering, hillslope processes and soil development. Then, students are asked to practise active learning by exploring the characteristics of and reasons for asymmetry in physical geography. Little reinforcement occurred between the virtual or field labs and the post-test. Thus, the research examines what additional knowledge was gained and retained above and beyond regular lectures. Readers wishing to visit Tempe Butte virtually can access the field trip at http://alliance.la.asu.edu/gph111/VirtualTempeButte/intro/overview.html (Figure 2).

Methods

Sponsored by the Arizona Board of Regents (ABOR), the second author developed a learner-centred geomorphology and writing-across-the-curriculum course to enable disabled students (cf. Hall *et al.*, 2004) to learn about the spectacular landforms of Arizona and the southwest. The virtual field trip to Tempe Butte (see Figure 2) represents one of the ABOR modules, subsequently modified for students in Introduction to Physical Geography.

Introductory physical geography classes at Arizona State University generally consist of three contact hours of lecture and three contact hours of a more learner-centred laboratory each week over the course of one, 16-week semester. A professor typically instructs 210 students in a large lecture hall, while graduate students teach six smaller break-out lab sessions of 35 students each. The authors collected data from two separate introductory physical geography courses conducted in consecutive spring semesters of study (year 1 and year 2).

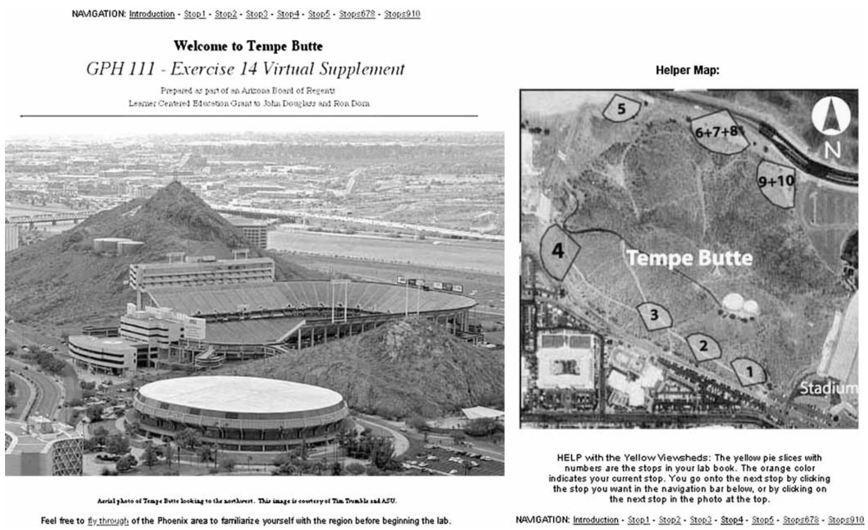

Figure 2. The portal students see when they log onto the virtual field trip website and aerial photographs provide users with orientation (left) and panoramic view sheds (right). Readers can access the field trip at: http://alliance.la.asu.edu/gph111/VirtualTempeButte/intro/overview.html

In the first year of study, we divided six lab sections into three teaching-method styles: virtual only; field only; and learning by both virtual and field. In order to control for teacher differences as much as possible, the two individuals who developed both the hardcopy lab and virtual trip modules (Douglass, Dorn) taught one laboratory class using each of these three methods. The lab-teaching assistants did not participate in instruction, but were present for assistance. The following year, we used the same methodology, but only one person (Dorn) taught all of the students. Our methods received human subjects review approval.

One week prior to the field trips, students were given a multiple-choice pre-test during their lecture class and learned of the purpose and methods of the study. Students were told that their performance on the pre-test had no bearing on their course grade, and that the grade would be based on completion of the laboratory exercise in their lab book and on the subsequent quiz given by their laboratory instructor.

The pre-test collected background information in addition to answers to 10 knowledge-based desert geomorphology questions (Table 1). Students were asked about their hobbies and where they grew up to see if age, gender and interests affect performance in virtual or field learning. The same 10 questions about desert geomorphology administered in the pre-test were given in a post-test so that question wording would not confound results. The post-test was administered on the Monday after spring break—six weeks after the pre-test and one month following instruction, in order to maximize our understanding of student retention.

In addition to completing the assessment described above, during the second year students were asked to write an essay after the post-test. Students were asked to "explain your connection to Tempe Butte in terms of its physical geography". They were given 10 minutes to write on a single piece of paper with a box 10 cm wide and 13 cm long.

Table 1. Information extracted by pre-test and post-test questions

Background information
• Sex Grouping: female, male • Age Grouping: 17–19, 20–22, 23–30, older than 30 • Do you prefer jobs where you can be outside? Almost all the time, Much of the time, A little bit of the time, None of the time. • Ethnicity/race: White (non-Hispanic), Black, Asian, Native American, Hispanic • Where did you grow up? Rural, Suburban, Urban • Do you enjoy playing video games? Yes very much, Sometimes, Rarely, Never • Where did you go to high school? Arizona California, Midwest, East coast, Other • Do you enjoy playing sports? Yes very much, Sometimes, Rarely, Never • Do you like to hike? Yes very much, Sometimes, Rarely, Never • What best describes your feelings about going out on a field trip to Tempe Butte for 2 hours? Excited, Better than sitting in the lab room, Don't care, Not looking forward to it, Dreading the experience
Descriptive knowledge questions on use of terms • What landform term best describes Tempe Butte? • Which statement is true based on the Law of Superposition? • Match: hogback, colluvium, calcrete and phreatophyte with plant with deep root system, a carbonate rich soil found in arid climates, angular rocks found on hill slopes, long linear ridge
Questions connecting features to geographic context • Where would you expect to find a xerophyte plant? • What clue helps determine if you are standing on the north side of Tempe Butte? • Salt River cobbles on the north side of Tempe Butte are considered? • The discovery of calcrete indicates?

In year 1 field-only students were taken to Tempe Butte, where Douglass or Dorn guided them on a walking tour of the field stops. Both the real and virtual field trips follow the same sequence (see Figure 1). Ten stops follow the paper laboratory exercise that all students completed and submitted to their laboratory instructors for their grade. Students were encouraged to make observations and ask questions. We admit that both Douglass and Dorn went into the experiment biased in favour of real field trips as the best way to learn, and thus both Douglass and Dorn were as enthusiastic as possible in the field presentation of a loved subject.

Students who participated in the virtual-only instruction were taken to a computer lab during their laboratory period. Douglass or Dorn instructed them on how to access and navigate the virtual lab while occasionally clarifying some of the field-trip text on an individual basis. Students accessed the virtual field trip on the Internet, where it is presented to them as a series of web pages following a three-tiered tree structure: index; field trip stops; and concepts. This navigational structure between pages follows what Taylor (1997) calls virtual physical geography. Students are also provided with a brief history of Tempe Butte on the index page as well as a navigational system built from an aerial photo of the site that indicates the location and view shed of each stop on the physical field trip (see Figure 2). Students can then click on any stop on the aerial photo to be brought to a page that outlines the key concepts relevant to that location. Panoramic pictures provide the same view students would have on the physical field trip with text and coloured boxes highlighting examples of important concepts. Students then click on the text to be taken to pages that specifically discuss the subject matter, providing close-up pictures, video footage and graphical models detailing geomorphic features.

Students who learned by both virtual and field trips were asked to complete the laboratory write-up in pencil, using the virtual field trip on the Internet, at home prior to going on the real field trip during their lab time. Of course, not all students did their homework prior to arrival for the real field trip, so student laboratory manuals were checked. Those failing to complete the virtual field trip at home had to be reclassified into the field-only group for data analysis.

Statistical Analysis

The data consist of complete responses from both the pre-test and post-test (see Table 1). Students who participated in one test but not the other were excluded. Students who completed both tests were subdivided into three groups, those who participated in only the virtual-only lab section, field-only lab section, and learning by both virtual and field labs. Students who did not complete the virtual lab prior to going on the physical field trip were reclassified into the field-only group, leaving only 12 in year 1 and 15 in year 2 who learned by both virtual and field methods. Our data matrix consisted of rows for each individual student completing the laboratory, pre-test and post-test and columns consisting of answers to each of the questions in Table 1.

T-tests and ANOVAs determined whether significant differences occurred among the different learning methods. Additional *t*-test and ANOVA statistical analyses helped determine whether student background on such variables as age, class, growing up in rural versus urban or suburban settings, and comfort with video gaming and computers might have influenced learning. These background data were first analysed on the entire dataset to determine whether differences in the way people learn are more important than the way information is presented, and then background information was disaggregated into learning styles before running additional tests.

Statistical analyses also compared the number of correct responses to individual questions for all three groups. Analysing individual questions determines whether there are particular sub-topics for which one method of instruction is better for student learning. An ANOVA on each test question supplements *t*-tests to determine if there is a significant difference between virtual only and field groups.

Qualitative Analysis of Essays

The essays were first subdivided into serious responses of students trying to explain their qualitative impressions of the physical geography of this desert landform and immature answers commenting on such items as the appearance of fellow students or their desire to be involved in a more fun activity elsewhere. Of the 59 mature answers 13 learned by both virtual and field trips, 24 completed only the virtual lab, and 32 were led in the field only. In trying to explain their 'connection to Tempe Butte in terms of its physical geography', students essays were grouped in terms of the major themes: (a) the number of elements of physical geography discussed (climate, soils, hydrology, biogeography, geomorphology, or earth material); (b) a change in appreciation for how they viewed the place; and (c) a change in how they thought about the place.

Results and Discussion

Test Validity

Analyses of pre-test and post-test results reveal construct validity for the tests and an overall improvement in comprehension of desert geomorphology among undergraduate students. The test group consisted of 108 students in year 1 and 121 in year 2. The post-test mean for the students was 68.1 per cent in year 1 and 70.5 per cent in year 2, revealing 27 and 25 per cent improvements over the 41.1 and 45.2 per cent pre-test means. The median scores for both classes indicate that a majority of students improved by answering three more questions correctly with a pre-test median of four correct answers to a post-test median of seven correct answers out of 10 questions. Two of the year 2 students achieved a perfect score on the pre-test, whereas in year 1 the highest score was eight. For both years the lowest score was zero. The range of scores in both post-tests shifted upward with several students earning perfect scores, while the lowest grades improved from zero to 3 in year 1 and to 2 in year 2. The distributions of scores for both tests are fairly consistent with a pre-test standard deviation of 1.94 questions (1.71 in year 2) and a post-test standard deviation of 1.85 questions (1.79 in year 2).

Aggregate Data

Students who learned only virtually, only in the field, or by both virtually and in the field maintained statistically indistinguishable scores in post-test results in both years, as revealed by *t*-tests and ANOVA. This study confirms the effectiveness of Internet-based instruction in general (Mendler *et al.*, 2002; Jain & Getis, 2003) and virtual field learning in particular (Wentz *et al.*, 1999; Spicer & Stratford, 2001). Spicer and Stratford (2001) concluded that students believe virtual field trips reinforce real field-trip experiences, but that they should not replace them. Interviews with our students in year 2 finishing up the 'virtual-only' exercise revealed that one-third of them would have strongly preferred to have learned the material on a real field trip, while approximately half liked the convenience of learning in an air-conditioned lab. In contrast, in year two about 40 per cent of those going into the field would have preferred the virtual-only alternative.

Disaggregated by Student Background

Student background does not appear to affect performance. There were no significant differences of mean scores within virtual-only or field-only data subsets for gender, age or ethnicity. The test group, with 108 participants in year 1 (121 in year 2), consists of 63 and 60 per cent women in years 1 and 2, respectively. In years 1 and 2, respectively, 65 per cent and 71 per cent are under age 19, while 27 and 22 per cent are between the ages of 20 and 22. The remaining are over the age of 23. The ethnicity of the dataset is dominantly Caucasian at 78.7 and 72 per cent, followed by Hispanic at 13.9 and 18 per cent in years 1 and 2. The remaining portion of the group consists of foreign students and Americans of Asian, Middle-Eastern and African descent.

More than half of the students grew up in suburban environments, a quarter in cities, and the remainder in rural communities; but no statistically significant differences exist in the post-test performance of these different populations. A majority of students in both sample years enjoy playing video games to some degree, but this characteristic does not produce a significant difference in the post-test scores. The class is fairly evenly divided between 59 and 55 per cent of the students attending high school in Arizona in years 1 and 2 versus elsewhere, but no statistically significant differences exist in where a student attended high school. Two-thirds of both classes enjoy hiking sometimes or often whereas one-third rarely does or does not like it at all; although not statistically significant in year 1, the post-test mean of students who like to hike in the field-only group was higher and statistically significant in year 2. No statistically significant differences occur between students in different colleges at Arizona State University; business, architecture, fine arts, education, and liberal arts and science students tested similarly.

Data for the field-only group shows no hint at a trend associating better scores with people looking forward to going into the field. Students who did not have any preference about the type of exercise they completed scored the highest means at 76 and 72 per cent compared with the lowest mean at 64 and 66 per cent in years 1 and 2 respectively, but these differences were not statistically significant.

Disaggregated by Individual Questions

Students performed well in six out of the 10 questions on both post-tests, essentially those items testing use of simple terms. Over 83 per cent (85 in year 2) of students answered these six questions correctly. Four of the questions with high levels of correct responses are matching problems. The fifth question asked students to identify the landform that best describes Tempe Butte and the sixth question asked students to determine which of several statements is true based on the Law of Superposition. Among these questions there were no significant differences in mean scores between virtual-only, field-only, and learning by both virtual and field experiences.

The four questions most students found challenging asked them to link terms and features to place. Of these four questions, two provided significant differences between virtual and field groups while the others did not produce significant differences even though groups with field exposure in both years generated higher ratios of correct responses. One question that produced significant differences between the mean scores of all three groups in both years asked students to link alluvium river cobbles to the north side of Tempe Butte being undercut by the Salt River. Only 24 and 26 per cent of students in the virtual-only group answered this question correctly in years 1 and 2, while 49 and 47 per cent of the field-only group responded correctly in years 1 and 2, respectively. Students from group that learned by both virtual and field trips performed best with 75 and 59 per cent of students providing the correct answer in years 1 and 2, respectively.

Students also had trouble mastering the concept that xerophytic plants like cacti dominate the south (sunny) side of Tempe Butte. *T*-tests found significant differences between the virtual-only and field-only groups. Field only students performed strongest with 42 and 51 per cent providing the correct response in years 1 and 2. Only 22 and 19 per cent of virtual students answered the question correctly in years 1 and 2. Students in the virtual/field group faired slightly higher than field-only students, but the percentage of correct responses is not significantly different in either year.

The remaining more challenging questions were similar, but did not produce significant differences between the groups. One of the questions relates to the concept that calcrete indicates landscape stability, a concept linked to a particular soil exposure on the south side of Tempe Butte. In years 1 and 2 respectively, 41 and 43 per cent of the virtual-only group, 49 and 55 per cent of the field-only group and 58 and 53 per cent virtual and field group answered this question correctly. However, these differences are not statistically significant.

The last question dealing with location assessed students' ability to link the presence of lichens and mosses to their occurrence on the shaded north side of Tempe Butte. The percentages of correct responses are not significantly different, but students who had a real field experience performed better with 34 and 40 per cent providing correct answers in comparison with 20 and 35 per cent of the virtual only group. Overall, the majority of students performed very poorly on this question, perhaps because this principle is taught at the end of the field trip when attention is waning.

While all students appeared to have difficulty with questions linking term or concept to location, the percentage of correct responses among students with field exposure was generally twice that of the virtual only group. Barta-Smith and Hathaway (2000) establish that students struggle to determine how facts, figures and pictures relate to each other in virtual field trips because few virtual field trips provide maps to help students establish geographic context. Even with an aerial photo on each page of the material presented (see Figure 2), this study found that virtual-only students still have trouble establishing location. It is possible that field-only students performed better in this respect because they built a geographic context of the site by physically walking between stops. When recalling questions on the test, they may have been able to better visualize where the material was presented to them.

Robson (2002) finds that travel to exotic places for fieldwork assists in student recruitment in addition to providing meaningful teaching and learning experiences. While Tempe Butte by most definitions is not an exotic place, it is important to consider its role of providing field-based learning opportunities in the recruitment of students. Since introductory courses play a strong role in recruiting students to the programme, real outside learning emphasizes the importance of field experiences to potential majors.

Qualitative Analysis of Essays

In year 2 when qualitative essays were added to the assessment, we did not detect a clear difference among virtual-only, field-only, and learning by both virtual and field with regard to how many elements of physical geography (climate, soils, hydrology, biogeography, geomorphology, or earth material) students presented in their essay. About half of the students in each learning group identified only one; about a quarter of the students identified only two, and the remainder identified three or more element of physical geography

In contrast, we did see major differences in how students appreciate place and how they now think about place. Twelve of the 13 students who did both the virtual lab and went into field felt better able to appreciate a natural landform, and 10 of the 13 said that they now think differently about landforms. Of 32 field-only responders, 25 felt better able to appreciate a natural landform and 22 now think differently. However, of the 24 virtual-only mature responders, only nine felt better able to appreciate a natural landform and eight now say they think differently when they look at landforms. Field-informed students appear to have a deeper connection to the subject, perhaps because of the greater experiential learning (cf. Healey & Jenkins, 2000) that takes place in the field.

Conclusion

Virtual field trips and real field trips appear to be equally effective methods for teaching students basic knowledge about desert geomorphology in introductory physical geography classes, regardless of student background and interest in outdoor activity. However, we do not think that this conclusion will be valid beyond introductory courses. When concepts increased in difficulty and required association with place, the importance of field learning increased to the point where students learning in the field showed statistically significant improvement over virtual-only learning. Furthermore, qualitative analysis of essays reveals that field experiences are far more effective at changing a student's appreciation of and thinking about natural landforms.

The overall picture, however, is clear. Virtual learning, in at least introductory courses, can provide a cost-effective alternative to field trips. Our desert geomorphology Tempe Butte module is open to all users, and thus might best be applied in any introductory course. Technology provides a means for undergraduate students to explore locations that prohibitive travel costs and political conditions would otherwise prevent, and these virtual trips can provide introductory students with an understanding of basic concepts.

Essay responses reveal, however, that virtual field trips are strongly directive and have limited capabilities for student interaction with the field. Simm and David (2002) believe student-developed research designs are important in more advanced undergraduate study to present students with opportunities to apply previous knowledge and learn from their own mistakes. Still, the expensive costs of fieldwork are reducing its role in undergraduate education—a growing concern among the academic community (McEwen, 1996; Kent *et al.*, 1997; Stainfield *et al.*, 2000). Our findings suggest that the virtual field trip can best be used to learn simple concepts and terms.

In the realm of physical geography, where even simple field trips can stress physically disabled students, our study indicates that virtual field trips offer physically disabled students a learning alternative to the local field trip (cf. Nairn, 1999; Hall *et al.*, 2004), although they may be less effective in linking process and place. By providing evidence for the validity of virtual learning, this study supports Taylor's (2000) call for studies on web-based educational methods to help dissolve "a division forming between technological optimists and skeptics of corporate powers, technology and 'radical' higher educational reform". Its results should help to ease the concerns of Rintala's (1998) call to question the appropriateness of computer technology in course development. Introductory students do gain basic knowledge through computers that is comparable to what they learn by interacting with the environment, at least in introductory courses where students reinforce basic terms and concepts through field studies

We are concerned, however, about the impacts virtual learning has on the social structure of the educational environment. With the self-directed nature of virtual field trips, it is very easy to eliminate the mentoring system Haffernan *et al.* (2002) speak of in the field experience. With few declared geography majors in US introductory courses, field trips offer potent means of recruiting students to geography, both for students who love the field and for students who need that casual interaction with an enthusiastic professor. For students visiting the field, we found that the passion and enthusiasm that instructors show in the subject matter instilled a deeper sense of physical geography operating at the field site.

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