Placing Ourselves on a Digital Earth: Sense of Place Geoscience Education in Crow Country

Teresa Cavazos Cohn,[1,a] Elisabeth Swanson,[2] Gail Whiteman Runs Him,[3] Dora Hugs,[4] Lisa Stevens,[5] and Devon Flamm[6]

ABSTRACT

Solutions to many environmental challenges now require geoscience expertise, knowledge of global interconnectedness, and an understanding of local cultural nuances, a combination for which geoscientists and our students may not be prepared. The Crow Indian Reservation and its borderlands are a microcosm of these challenges, where geoscience expertise must integrate modern science and local worldviews. We propose sense of place education alongside the use of a digital Earth tool in classrooms as a means of (1) engaging American Indian students and teachers in geoscience, (2) using technology to help students apply geoscience expertise to land management issues in their region, and (3) preparing students for an increasingly intercultural and interdisciplinary future. Developed through a collaborative effort among university geoscientists, tribal college faculty, K–8 teachers, and Crow cultural consultants, the Crow Country Digital Globe integrates the local and global, as well as the experiential and virtual, in geoscience teaching. © *2014 National Association of Geoscience Teachers*. [DOI: 10.5408/12-404.1]

Key words: sense of place, American Indian education, digital Earth, rephotography

INTRODUCTION

A thorough understanding of weather, climate, hydrology, physical geography, and geology is imperative in addressing some of the great environmental challenges of our time. As the human population continues to grow on an Earth increasingly stressed for resources, it is perhaps more important than ever that students comprehend core concepts of the geosciences (National Research Council, 2012). Yet many pressing issues, such as climate change and hydrological shifts, exist in increasingly interdisciplinary and intercultural contexts for which we—and our students—may not be prepared.

As evidenced by this special issue, the Earth Sciences community is increasingly concerned with the diversity of its membership. Indeed, its literature examines everything from barriers that limit the engagement of certain cultures (Lee and Buxton, 2008) to the culture of science itself (Lewis and Baker, 2010). Whether its motivation to understand diversity arises from inequity in education (Lee, 2003), a lack of general geoscience literacy (Lewis and Baker, 2010), or problems solving environmental issues that cross cultural boundaries, ''Failure to improve diversity could have important ramifications for the economic, social, and scientific health of our fields'' (American Geophysical Union, 2002) and of our shared world.

The Big Sky Science Partnership (BSSP) addresses similar diversity concerns in Montana by engaging tribal representatives, university scientists, and professional educators in order to improve American Indian science achievement in Montana schools. We specifically focus on the Crow Indian Reservation and its border regions to address three main issues: (1) the underrepresentation of American Indian students and teachers in geosciences, (2) the complex intercultural relationships involved in effective geoscience teaching and learning, and (3) the ways technology might help students apply intercultural geoscience expertise to land management issues in their region.

The National Center for Education Statistics finds that 4th-, 8th-, and 12th-grade American Indian or Alaska Native students score below average in science assessments (National Center for Education Statistics, 2005). Nationally, American Indian and Alaska Natives receive only 30 bachelor's degrees in the geosciences each year and have earned only 51 of 21,000 doctorate degrees awarded from 1973 to 2004 (Czujko and Nicholson, 2012). Montana's Office of Public Instruction (2010) finds similar results in the state; when comparing the two largest racial groups—American Indian and white—it finds that 63% of white students achieve proficiency in science, compared to 29% of American Indian students (2009–2010) (4th graders achieve 72% versus 36%, 8th graders achieve 68% versus 31%, and 10th graders achieve 47% versus 16%). This trend of underrepresentation in the geosciences is of particular concern in Montana, where 6.4% of the population (U.S. Census Bureau, 2011) and 11.8% of students are American Indian (Office of Public Instruction, 2010), and more than 5% of the land base—more than 20,000 km^2, or almost 5 million acres—is managed by tribes (Natural Resource Information System, 2011). The Crow Reservation's exterior boundaries alone encompass 9,235 km^2, or 2,282,000 million

Received 15 December 2013; revised 10 December 2013; accepted 2 February 2014; published online 28 May 2014.

[1]Environmental Humanities Graduate Program, University of Utah, 255 S. Central Campus Drive, Room 2100, Salt Lake City, Utah 84112, USA
[2]Big Sky Science Partnership, Science/Math Resource Center, Montana State University, 401 Linfield Hall, Bozeman, Montana 59717, USA
[3]Little Big Horn College, 8645 South Weaver Drive, Crow Agency, Montana 59022, USA
[4]St. Charles Mission School, 29 Gap Road, Pryor, Montana 59066, USA
[5]Crow Agency School, 101 Makata Street, Crow Agency, Montana 59022, USA
[6]Hardin Intermediate School, 631 West Fifth Street, Hardin, Montana 59034, USA
[a]Author to whom correspondence should be addressed. Electronic mail: teresa.cohn@utah.edu. Tel.: 801-581-6214. Fax: 801-585-5190

acres (Bureau of Indian Affairs, 2012), exceeding the size of Yellowstone National Park. Thus, Montana tribes manage substantial amounts of lands with relatively little professional geoscience expertise.

Science achievement, while important, is not the only indicator of Earth systems expertise, particularly when applied to local contexts. American Indians and First Nations peoples continue to use sophisticated knowledge systems that have evolved over centuries on this continent (Kawagley, 1995; Cajete, 2000; Deloria and Wildcat, 2001). Moreover, these systems may stress increasingly important science concepts such as systems science, interconnectedness, and resilience (Kawagley, 2001; Peat, 2002; Bang et al., 2007). This type of expertise becomes more valuable as scholars stress that globalization and resource scarcity call for cross-disciplinary and cross-cultural teaching and for curriculum "structured like a web or complex adaptive network" (Taylor, 2009). Specialization in fragmented disciplines may become an impediment to solving systemic problems; a "oneness" of thinking may prove more valuable since is does not require students "to break themselves and the world into pieces" (Bohm, 1980).

Land management in this region exemplifies the necessity for cross-disciplinary and cross-cultural thinking in the geosciences; for example, hydrological features may carry with them a tangle of water rights (including federal reserve), power relationships, and beliefs on how water should be used. Rock outcrops may indicate coal seams or sacred sites on land designated as allotted, tribal, or fee. In this region, geoscientists must include tradition and technology in their expertise. Geoscience teaching must do the same.

The Crow Indian Reservation and its borderlands represent a microcosm of an increasingly populated and multicultural globe in which geoscientists must work collectively across boundaries. Resources such as water and a changing climate do not heed human boundaries between cultures or disciplines.

BACKGROUND: PLACING OURSELVES ON A DIGITAL EARTH

The BSSP is specifically concerned with increasing quality Earth Science education tools appropriate for American Indian classrooms and multicultural classrooms with a large percentage of American Indians. In order to develop culturally appropriate materials, we draw upon two aspects of literature relevant and effective in the context of our students: (1) sense of place education that minimizes boundaries between modern science and local cultures and (2) a digital or virtual Earth as a classroom tool for both geoscience teaching and seamless "border crossing."

A growing body of literature suggests that engaging sense of place is a central and effective concept in science teaching in American Indian communities (Kawagley, 1995; Cajete, 2000; Gruenewald, 2003; Semken and Brandt, 2010) since the instruction of concrete geoscience concepts in local places may engage students better than more abstract global syntheses (Riggs, 2005; Semken, 2005; Semken et al., 2009; van der Hoeven Kraft et al., 2011). In this context, "place" is more than a physical location on Earth; it is "the process by which people give meaning to location, particularly to how they create social geographies that are rooted in community" (Wyckoff, 1999). "Sense of place" is then a combination of physical environment, historical geographies, and the "invisible landscape" of value systems, cultural beliefs, experiences, and interpretations of place, which "give order, structure, and value to the geographical world" (Ryden, 1993). If geoscience concepts are taught when engaging the invisible landscape, the physical world of geoscience is not removed from the world of our cultures and minds. As Meinig (1979) suggests, "any landscape is composed not only of what lies before our eyes but what lies within our heads," and what lies within our heads is imperative in navigating not just physical geographies but also the moral geographies that remind us who we are. As Basso (1996) writes of the Apache, "Beyond the visible reality of place lies a moral reality which they themselves have come to embody.... It is this interior landscape—this landscape of the moral imagination—that most deeply influences their vital sense of place, and also, I believe, their unshakable sense of self."

Engaging students' sense of place in teaching is thought to facilitate seamless transitions—often called border crossings—between students' everyday lives and science lessons (Aikenhead, 1997; Aikenhead and Jegede, 1999; Warren et al., 2001). Unsuccessful border crossings may impede student interest and success in science and may promote thinking that divides science from life. Teachers must thus become "cultural brokers" who explicitly help students to transition between the cultures of their daily lives and the culture of science, without asking students to choose one of the two (Aikenhead, 1997).

Technology is often viewed as separate from indigenous value systems and sense of place education. However, a recent body of literature finds that sense of place education is compatible and effective with digital Earth technology, such as Google Earth (Monet and Greene, 2012). While digital Earth technology is not a substitute for field experiences, it addresses the reality of many classrooms in which field experiences are rare. A digital Earth tool is a secondary but valuable means of engaging students with their local landscape.

Digital Earth technology is also a tool for teaching the interconnectedness of the multicultural global community (Kerski, 2008; Schultz et al., 2008). Spatially, it depicts Earth as one seamless planet shaped by global systems—such as the water and carbon cycles—and influenced by many cultures and value systems with separate global footprints. Most geobrowsers offer layers activated by users, who flip between them. For example, a user may quickly move between a map of indigenous place-names and a geological map or may activate a transparency between them so that both simultaneously represent perspectives of one whole globe.

Sense of place education that uses digital Earth technology is ideal for understanding contexts such as ours, in which the multicultural makeup of the classroom reflects that of our multicultural communities. Just as students of the global community need to understand one another's cultures to be able to successfully manage environmental issues that affect Earth, the students in our classrooms need to manage local resources across cultural divides. Without the self-understanding inherent in sense of place, "we cannot hope for enduring solutions to environmental problems, which are fundamentally human problems" (Tuan, 1974).

DYNAMIC CULTURES ON A DYNAMIC EARTH

The Dynamic Earth is a pilot project of the BSSP, whose specific goals are to (1) use a collaborative model of curriculum development, regional in scope but aligned with the specific needs of individual classrooms, and (2) pilot the effectiveness of using rephotography and digital Earth technology to engage students in geoscience concepts locally.

Collaborative Curriculum Development

The BSSP has developed a science education community on and around the Crow Indian Reservation over the past 6 y; thus, the Dynamic Earth project was built upon already existing relationships among Montana State University scientists, Little Big Horn College faculty, local cultural consultants, and local teachers. Our teacher cohort included Crow and nonnative teachers representing classrooms that ranged from 100% to 72% American Indian students in both public and private schools. We piloted our project in collaboration with eight teachers who instructed two 4th-grade and one 8th-grade classrooms in a public school just outside the reservation boundary, two 5th-grade classrooms and one 1st-grade classroom in two public schools within reservation boundaries, a combined 5th- and 6th-grade classroom in a private school within reservation boundaries, and two tribal college courses (agriculture and general science). The 1st-grade teacher withdrew from the pilot as a result of school restructuring.

Two cultural consultants played critical roles in the development of a digital Earth tool and its focus on important local landscape features. For example, one consultant sorted through a collection of historical photographs collected from several archives, graded them according to cultural importance, identified the location of features on the landscape, and—when culturally appropriate—obtained land owner permissions and rephotographed them. A second consultant, and fluent Crow speaker, guided the development of appropriate cultural integration in lessons.

The teachers in our cohort similarly collaborated with our geographer to develop relevant materials for their classrooms. Several teachers stressed the need for the integration of new resources into the existing curriculum, rather than adding additional curricula to their already overloaded requirements. Our team thus identified the Dynamic Earth project as a geoscience concept that fit broadly into content standards, as well as into specific classroom units the teachers had already developed. Finally, our geographer and the teachers worked together to develop lessons for their specific needs. For example, the 4th- and 5th-grade teachers decided to use a severe 2011 flood event to exemplify the changing Earth, while the combined 5th- and 6th-grade teacher developed materials that allowed her to move seamlessly between Crow culture and science topics in the valley known as the Home of the Mountain Crow. Each lesson incorporated cultural, ecological, and geophysical change.

Development of Digital Earth Tools

We used three data sets to develop the Crow Country Digital Globe. First, through the state of Montana's Natural Resource Information System (NRIS) geodata bundler, we gathered a variety of local mapping data, including hydrology, geology, soils, land use, land ownership, and place-names; we used ArcGIS 9.3 software to create local maps appropriate for our classrooms; and we created keyhole markup language (KML) files with clickable layers compatible for use in Google Earth (Fig. 1). Second, we downloaded 1953 U.S. Geological Survey (USGS) aerial photography of specific areas, georeferenced them, and exported them as layers compatible with Google Earth (Fig. 2). Third, we collected a variety of historical photographs from archives of western imagery, acquired appropriate education use permissions, rephotographed the areas in summer 2011, and imported the paired images into Google Earth as overlays attached to appropriate geographical coordinates (Fig. 3). We additionally imported local aerial flood photographs from 2011 to their appropriate geographical location, inserted National Oceanic and Atmospheric Administration (NOAA) water vapor loops, and placed stream gauge data next to major waterways. Each teacher computer and all student computers (when available) were provided with a set of layers in Google Earth compatible to a specific lesson. The series of clickable layers allowed students and teachers to interact with repeat ground photography, aerial photography, and several layers of maps.

PILOT LESSONS AND RESULTS

The Digital Earth pilot lesson took place in two stages. During the first phase we assessed how well technology functioned under various configurations and evaluated initial effectiveness; during the second phase we conducted pre- and postassessment surveys.

Phase 1

Several computer configurations were tested in five classrooms during Phase 1, which included some combination of teacher instruction on a Promethean board, individual or paired computer use by students either on classroom laptops or in computer labs, and imagery on student response worksheets. Each of the five classrooms experienced some difficulty with technology that was not anticipated in tests prior to lessons. In three classrooms, problems related to image loading speed when multiple student computers ran Google Earth simultaneously. In two additional classrooms, and despite coordination with the school's information technology specialist, schoolwide censors prevented Google Earth images from loading on student computers. This was partially remedied by switching to a teacher laptop running on a Promethean board, but students were not able to engage in maps on their own computers. We deduced that the ideal scenario included a teacher introduction on a Promethean board followed by guided student exploration on either individual or shared computers loaded with a subset of available maps and photographs.

Informal interactions with teachers and assessments of student engagement led us to conclude that further evaluation of digital Earth technology was worthwhile.

Phase 2

During Phase 2 of our pilot, we conducted pre- and postassessment surveys in two 5th-grade classrooms and one 4th-grade classroom, as well as a student evaluation in a

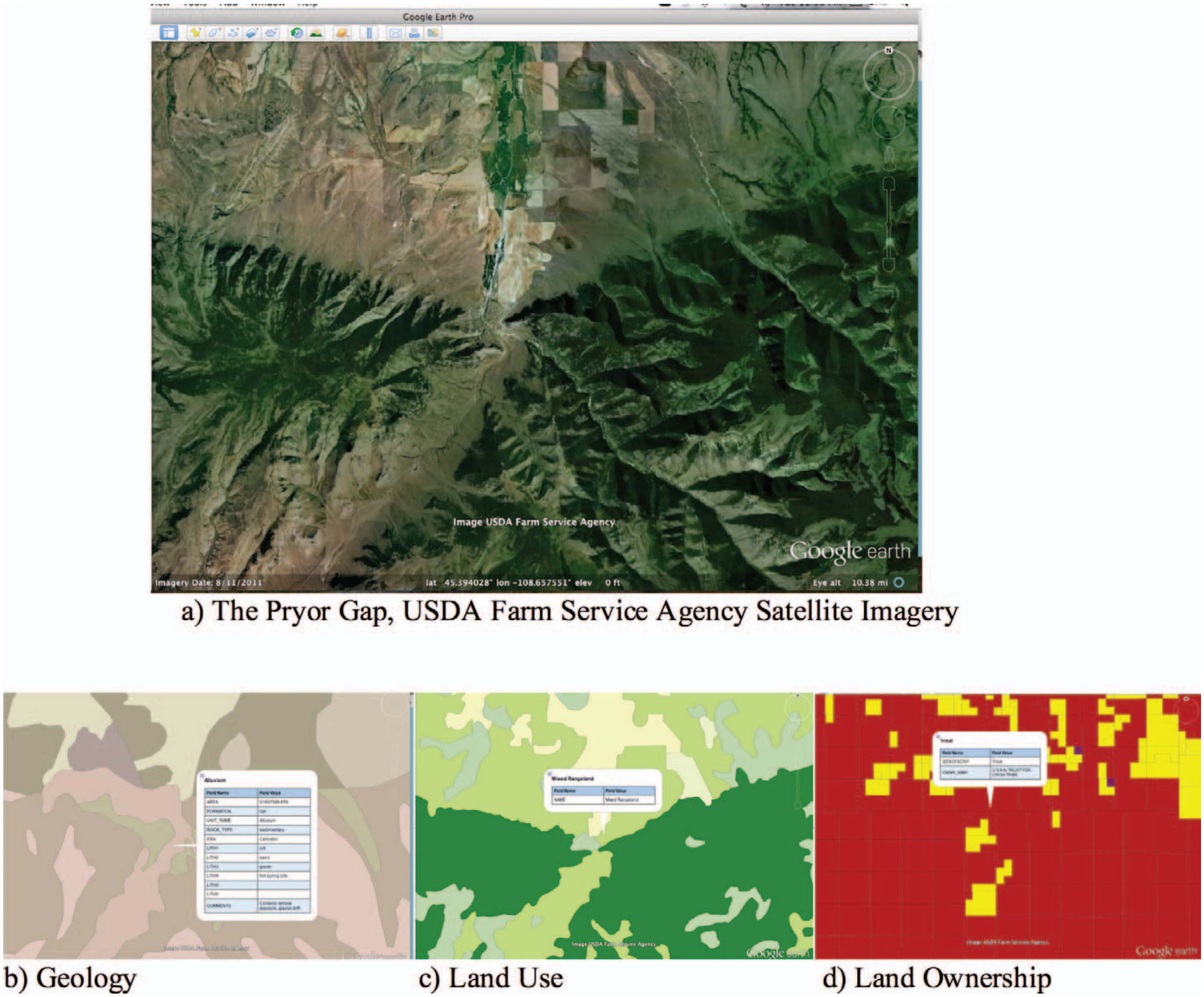

FIGURE 1: U.S. Department of Agriculture Farm Service Agency image of the Pryor Gap depicted in Google Earth. (a) Geology layer of the same location, with a bubble describing geological specifications (e.g., area, formation, rock type, lithology, and era). Layer courtesy of Montana NRIS and USGS. (b) Land use layer, with bubble describing land use type (e.g., mixed rangeland, evergreen forest, wetland, or sand). Layer courtesy of Montana NRIS, USGS, and the Montana State Library. (c) Land ownership layer, with bubble describing specifications of land owner type (e.g., tribal or private) and owner name. Layer courtesy of Montana NRIS and the Montana Natural Heritage Program.

combined 5th- and 6th-grade classroom, each detailed below. Pilot classrooms included three schools.

The 4th- and 5th-grade lessons (60 and 75 min, respectively) were focused on water, a critical environmental focus in this arid region of the American West that shapes both cultural and physical landscapes. Lessons included imagery from a memorable local flood event of 2011, which inundated portions of students' communities. Lessons were designed (1) to test the efficacy of digital Earth technology as a teaching tool of Earth Science concepts and (2) to engage sense of place through the use of local imagery to help students explore the questions "How does water change the land?" and "How does water shape the land and our communities?" The instructional team assembled to assist in this phase of the pilot consisted of a geoscientist, the regular classroom teacher, the school's instructional technology teacher, and an instructional coach.

Students were first introduced to Google Earth map layers by instructors, including (1) a *Streams* layer with local streams highlighted in blue and names and distances of streams appearing in bubbles when clicked; (2) an *Aerial Photography 1953* layer that projected a black-and-white image of a local riparian area in 1953, allowing students to click back and forth to see landscape changes over time; (3) a *Precipitation* layer that showed areas of different amounts of precipitation in varying shades of blue and specific precipitation amounts in bubbles when clicked (e.g., 18 inches); (4) a NOAA *Western Water Vapor Loop* displaying

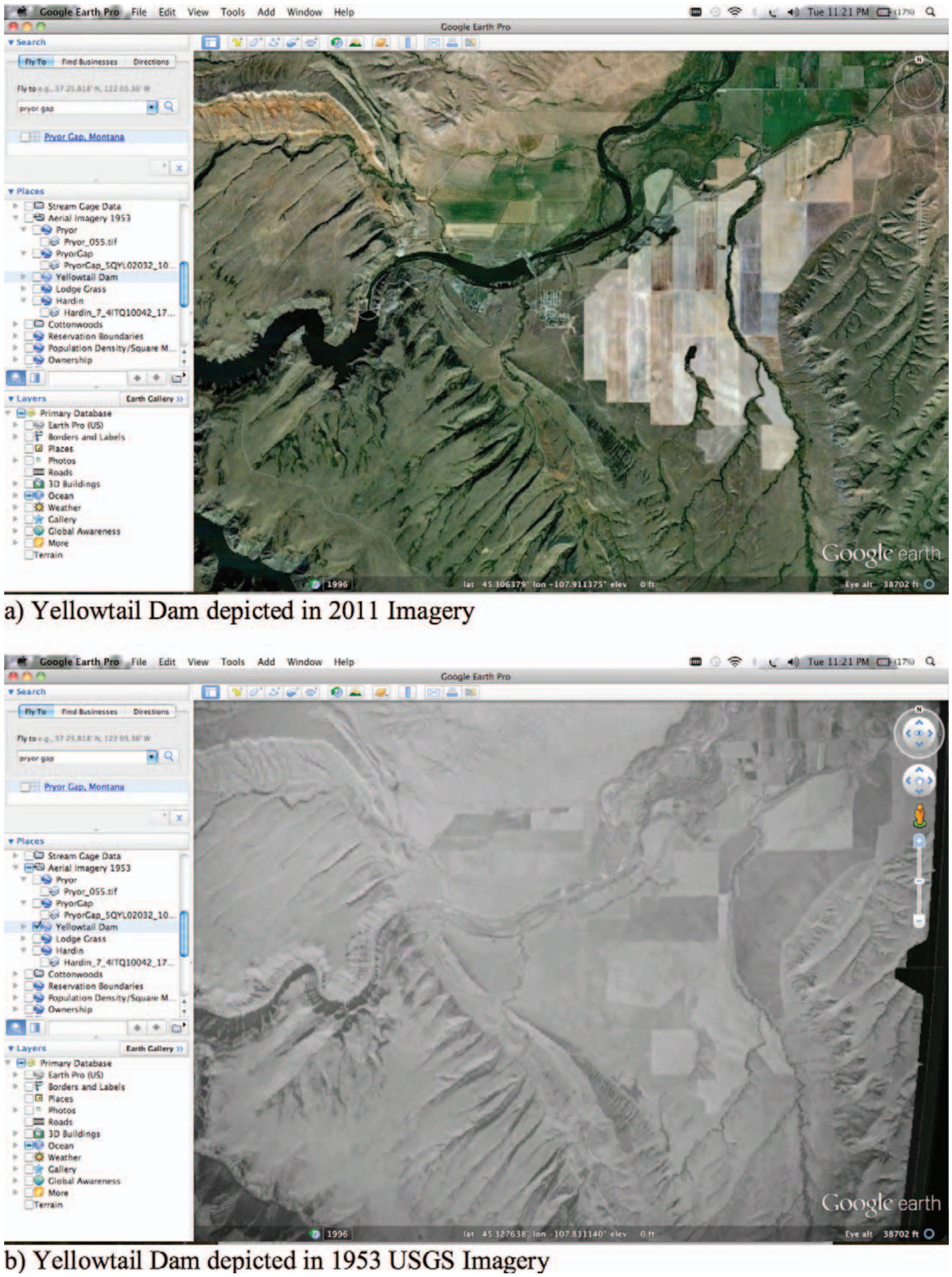

FIGURE 2: (a) Yellowtail Dam depicted in 2011 Google Earth imagery. (b) Yellowtail Dam depicted in 1953 georeferenced black-and-white aerial imagery. Black-and-white image courtesy of USGS.

the day's movement of water vapor across the western U.S.; and (5) *Local Flood Photographs* showing georeferenced aerial photographs taken during the 2011 floods and projected over the local landscape. The instructor exemplified the ways in which students could use these layers to both ask and respond to questions. Students then explored the layers either individually or in pairs on computers that had been loaded with the five layers. Students were asked to respond in writing to specific questions about their local landscape and then make deductions based on what they had learned. Students completed both pre- and postassessments.

The pilot lesson in the combined 5th- and 6th-grade classroom differed from water lessons at other schools and instead focused on repeat photography and changes in the cultural and physical landscape over 100-y intervals. A 60-min lesson included current Google Earth layers, aerial photographs of pre- and postlesson images of the nearby Yellowtail Dam area, and repeat historical images of the Home of the Mountain Crow. This lesson was guided by a geoscientist and cultural consultant using a Promethean board and accompanied by imagery printed on individual

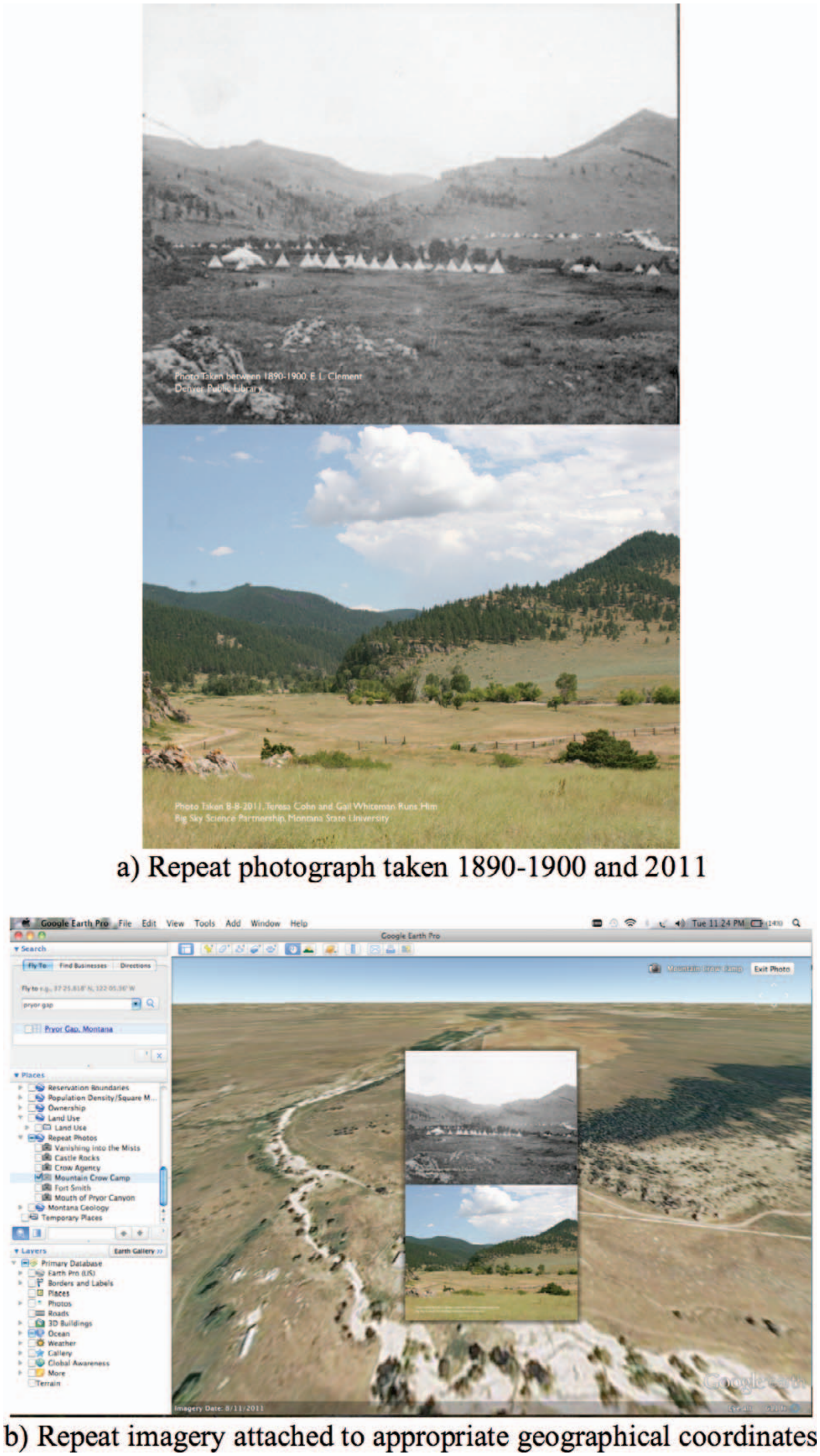

FIGURE 3: Repeat images of the Home of the Mountain Crow. (a) Black-and-white image taken 1890–1900 by E.L. Clement. Image courtesy of the Denver Public Library. (b) Image retaken 8 August 2011 by Teresa Cavazos Cohn and Gail White Man Runs Him. (c) Paired images superimposed on appropriate virtual coordinates using Google Earth.

TABLE I: Fifth-Graders' Responses to Pre- and Postassessment Questions Regarding Digital Earth Lesson.

Questions and Responses (*N* = 22)
1. Have you ever used Google Earth before? (presurvey) Yes 6 No 11 Not sure 5
Sample responses
"No I never ever used Google Earth before... and my friends have never seen it too."
"My cousins... never heard about it, and my friends and my aunties and uncles."
"I used it, but my mom and dad never used it because they don't need it."
2. If so, how would you describe it to a friend who has never used it? (presurvey)
Sample responses and patterns
Looking things up and search capability
"On the Internet, it is good to look things up."
"I would show 'my friend' on my computer first... say it's Google, but it's a map."
"It helps to find places around the world."
Ease of movement
"You can move around the little man."
Zooming-in capability
3. Is Google Earth a helpful way to learn science? (postsurvey) Yes 20 No 1 Not sure 1
Sample responses and patterns
Seeing one's home and town (2); local schools, river, ponds, and lakes (1); other states or countries (1); or Earth (3)
Learning about annual precipitation (1) or "how much rain is by our house and in the river" (2).
"Helps us find out about the water, oceans, and everything, like you're a scientist."
Good for homework (1)
Ease of movement
"You can type what you want then go. Zoom in there, you will find it."
"It's so fun to see everything around you."
Not helpful
"We can't learn about space and chemicals."

student worksheets; students did not work directly on computers.

Fifth-Grade Results

In written pre- and postassessments (Tables I and II), more than two-thirds of the 22 students reported that they could not recall using Google Earth prior to the water lesson, a finding confirmed by the school's technology teacher. Two students volunteered that they, their families, and their friends were all unfamiliar with this application. As one of the students commented, "No I never ever used Google Earth before... and my friends have never seen it too." Another student who had used Google Earth stated, "I used it, but my mom and dad never used it because they don't need it," adding to the sense that Google Earth was not commonly used in the students' communities.

When asked how they would describe Google Earth to a friend, the six 5th graders who were familiar with the application spoke about search capabilities ("It's Google, but it's a map"), the ease and quickness of movement enhanced graphically with a "little man" whose movements could be guided by the students, and the ability to find places around the world.

After completing the water lesson using the digital Earth tool, 20 of the 22 5th graders reported on the postassessment that Google Earth was a helpful way to learn science (Table I). The students wrote about seeing their homes; their schools; nearby towns; distant states and countries; natural features like rivers, ponds, and lakes; and other surface features of Earth. They spoke of using Google Earth to learn, for example, about annual precipitation patterns, including "how much rain is by our house and in the river," and finding out "about the water, oceans, and everything, like you're a scientist." One student noted the ease of movement afforded by virtual travel, saying, "You can type what you want then go. Zoom in there, you will find it." Students' responses conveyed engagement as they explored portions of their tribe's land and water domain of about 2 million square acres, seeing both familiar and unexplored places through new digital lenses. As one student remarked, "It's

TABLE II: Fifth-Graders' Responses to Survey Questions Before and After Digital Earth Lesson.[1]

Questions and Responses ($N = 22$)	**Pre**	**Post**
1. Name the river closest to your home.	18	22
Change of post response?		6
2. Where the water comes from	8	8
Change of post response?		6
3. Where it goes	7	6
Change of post response?		4
4. Why did the 2011 floods take place?		
Response patterns		
It rained a lot and that filled the rivers	8	1
It (the river) got bigger and flooded	1	0
Snow/ice from the mts	2	2
Snow/ice from the mts, plus rain	2	9
Too much water from the mts	2	1
Melting	4	6
I don't know	2	0
Confusing or irrelevant answer	3	3
Missing response	0	6
Place an X (on the image below) where you would build your home. Why would you build your home there?		
Response patterns		
Away from the river	2	4
Safe from flooding	3	5
Safety from flooding vs. other values	0	1
Close the river or other bodies of water	3	2
Quiet, peaceful, safe	5	1
Private, hard to find	1	0
Trees (a few trees → woods)	5	0
Ample space (from "enough" to "super big")	3	0
Suitable for keeping or riding horses	3	2
Room for gardening, farming, or ranching	3	0
Suitable habitat for wildlife	1	0
Hunting	3	2
Fishing	1	2
Walking or hiking	3	3
Space to play (basketball, swimming, other)	2	3
Love the area or community	2	1

[1]Pre = preassessment; post = postassessment; mts = mountains.

so fun. You can see the river and lakes and ponds, and schools, and your house." Conversely, another student noted a drawback of Google Earth as a science learning tool: "We can't learn about space and chemicals."

Pre- and postassessments were designed to assess the specific information students were asked to find (rivers near their home communities), in addition to the knowledge they gained indirectly through their explorations of maps and photographs (e.g., flooding and where best to build a home). In pre- and postassessments, students were asked to name the river nearest to their home and describe its movement (e.g., where it comes from and goes to). Of the 22 students, 18 were able to accurately name the river closest to their home on the postassessment, compared to 10 students on the preassessment (Table II). The inventory of rivers the students identified included three major tributaries of the Yellowstone. Just a handful of students showed improved understanding of where the water from the river closest to home comes from and where it goes to. In some cases, the original answers were sufficient to correctly answer the question.

Slightly more students exemplified more detailed knowledge of how flooding affected the area after the lesson. When asked why the 2011 floods took place, a dramatic event that affected most of the communities where the students lived, nine students were able to identify the impact of snow accumulation from the mountains, along with unusually heavy spring rain, after the lesson compared to just two students on the preassessment. When asked to place an X on an aerial photograph identifying a location in which the student would like to build a home, eight students changed their location as a result of the lesson, and six cited flooding as the reason. One student's response exemplified the complexity of the decision about where to build a home, exacerbated by the memory of recent flooding. On the preassessment she said, "I love (my community). When I am a grown person I want to live there. Nice and peaceful." On the postassessment, she added, "I love my home. I would live there in (my community). But if my house got flooded all over?" Students' responses on the pre- and postassessments about why they would build their homes on particular locations varied widely, reflecting different values and experiences. Building away from the river and safety from flooding were factors in 10 students' postlesson responses, yet two students still preferred proximity to water after the lesson. Other reasons for situating one's home ranged from peace, quiet, and privacy to gardening, farming, ranching, and room for horses; to hunting, fishing, hiking, and being among the trees; and to space for play and recreation. It may be significant that none of these rural students expressed a desire to alter the character of the wilderness and agricultural lands shown on the aerial image.

Fourth-Grade Results

Fourth-grade students had been exposed to Google Maps in their library class prior to our lesson but not specifically to Google Earth. Just over half of the students (8 out of 15), reported that they had used Google Earth (Tables III and IV). Students who were already familiar with Google Earth commented upon the ability to see cities and town, oceans, and Earth and, more recently, the ability to explore the moon and Mars using the same software technologies. The students noted the search capabilities, stating that "You just look up places and Google places," and "You can read about stuff and it's 3-D." Like their 5th-grade counterparts, they were enthusiastic about the ability to "click anywhere you want, and it will take you there," to change settings quickly, and to zoom in to the desired location.

All 15 students believed that Google Earth is a good way to learn science, and several noted the link between local landscape and science (Table III); for example, "Google Earth is helpful to learn about science because you can learn about everything around you and I thought that was cool," and "It helps you learn about rivers, precipitation, and maps. It helps you know what rivers are close to you." Students also described the ability to compare elevations, weather patterns, and animal distribution across locations.

All 4th-grade students accurately named the river or stream closest to their home on the postassessment (Table IV), identifying seven local creeks, coulees, and rivers with precision, compared to two students who successfully answering this question on the preassessment. Only a handful of the students responded to a question in the pre- and postassessments about where water from their closest-to-home river originates and goes. Two students responded postlesson that the water came from the nearby mountains that anchored the watershed in this region, and two other students named the streams or rivers that were connected to their closest waterway.

Almost all students responding to the question "Does a river change over time?" answered affirmatively on the pre- and postassessments. The students included more than a dozen categories of supporting evidence. For example, they noted that riverbanks eroded; rock, soil, and debris are deposited in rivers; water is a force shifting sediments downstream; and rivers get bigger, smaller, spread out, and may dry up.

Due to technical difficulties, most of the 4th-grade students' computers did not display flood photographs. Thus, when asked about the location of a preferred home in an aerial photograph, six students reported a change in location before and after the lesson and seven students reported no change. On the postassessment, only two students noted flooding as a problem and accordingly placed their proposed building sites away from the river. As one of the students explained, her proposed home site was "not too close to the river just in case of a flood. It is by the forest, it is mainly flat land." We did not consider this portion of the lesson successful, yet the resulting responses from the students revealed their thinking and values regarding land and water. For example, the students recognized the importance of water in this western landscape; they noted the uses and beauty of trees in the local environment, shelter from the wind, and ample space for play.

Fifth- and Sixth-Grade Results

Though located in an isolated rural area, the majority of 5th and 6th graders in the combined classroom reported that they had experienced Google Earth prior to the lesson. When surveyed on their favorite part of their lesson, 13 out of 18 of the students described their exploration of the local landscape (Table V). Their comments broadly portrayed recognition of local landscape features ("we got to see our town that we live in") to more specific signifiers of local place ("I saw Martin's truck at the post office"[1] and "we seen my home"). The five students who did not describe local images as their favorite part of the lesson described repeat photographs, such as "when we saw 100 years ago when my great grandparents or great-great grandparents lived." Several students expressed frustration with slow computer speed.

DISCUSSION AND IMPLICATIONS FOR TEACHING

Preliminary results from Phase 1 and Phase 2 of our pilot lessons indicate that the digital Earth tool (1) is compatible with technology available in rural classrooms, particularly if bandwidth is sufficient to quickly load images on multiple computers; (2) appears to engage students and has the potential to help them learn science through the sense of place they associate with local landscapes; and (3) supports the incorporation of both cultural and geophysical landscapes in integrated lessons.

[1]Name changed for privacy purposes.

TABLE III: Fourth-Graders' Responses to Pre- and Postassessment Questions Regarding Digital Earth Lesson.

Questions and Responses (*N* = 15)
1. Have you ever used Google Earth before? Yes = 8 No = 4 Not sure = 2 No response = 1
If so, how would you describe it to a friend who has never used it? (presurvey)
Sample responses and patterns
Seeing cities and towns (3), oceans, Earth (3), the moon, and Mars
Looking things up and search capability
"You can read about stuff and it's 3-D."
"You just look up places and Google places."
Ease of movement
"You can look around the world, you can change settings. . ., you can fly on an airplane."
"It is an online map of the World.. . . You can click anywhere you want, and it will take you there."
Zooming-in capability (3)
"You look at the Earth and move it around until you find where you want to go. Then you zoom in and you see it."
Choice and autonomy
"Search what town you want, then you can zoom in.. . . Put the little orange guy (where) you want him to go and after that you can explore."
Visual qualities
"It's like glowing and 3-D."
2. Is Google Earth a helpful way to learn science? (postsurvey) Yes = 15 No = 0
Sample responses and patterns
Going places
"Go to other (places) you haven't been to and you can get to the moon and Mars."
"You can go to wherever you want. You can look at all the amazing things about that place."
Seeing trees, land, mountains, and rain
Learning about "a lot science stuff," elevation, precipitation, and Earth (2)
"It tells a map of the whole world."
"It helps you know what rivers are close to you."
"You can compare and you can look at the weather."
"You'll know each state or country so if they ask you where an animal lives. . ."
"You can know the precipitation. You can learn a lot off of Google Earth."
It's cool
"You can learn about everything around you and I thought that was cool."
Scientists use it
"Like a teacher from (a local university) used it and she is a scientist."

We found three particular themes interesting and relevant to the development of future lessons in diverse locations: student engagement, integrating the local and the global, and strategies for professional development and future use.

Student Engagement: Pros and Cons

Postassessments, as well as what our team observed during classroom lessons, indicate that students are engaged by digital Earth technology; however, their interest in their exploration of the world may exceed that of a focused lesson. For example, when one 5th-grade student discovered that the "street view" feature allowed her to see her house as if she were standing in front of it, several other students began to explore their neighborhoods in the same way. Another student discovered a feature that allowed him to observe outer space. This was not necessarily negative. For example, students incorporated their local knowledge of specific geographical locations (e.g., access to water for people, livestock, and wildlife) in their written discussions of riparian

TABLE IV: Fourth Graders' Responses to Survey Questions Before and After Digital Earth Lesson.[1]

Questions and Responses ($N = 15$)	Pre	Post
1. Name the river closest to your home.	8	15
Change of post response?		13
2. Where the water comes from	1	5
Change of post response?		5
3. Where it goes	1	3
Change post response?		3
4. Does a river change over time?		
Yes	13	14
No	1	1
No response	1	0
5. Why or why not?		
Response patterns		
Erosion of the river banks	2	2
Rocks, dirt, or other sediments in the river	1	0
Sediments buildup and/or movement over time	0	2
Water moves and shifts rocks, dirt, and debris	4	1
Rivers grind up rocks	1	0
River bed erodes down	4	1
River direction is altered due to flooding, etc.	1	2
River gets bigger, smaller, and spreads out	2	1
Some rivers dry up	0	1
Must change since there are so many rivers	1	2
Merge with other streams or rivers	1	1
Flowing past houses and towns alters rivers	0	1
Because the world keeps changing	1	0
I don't know	1	1
Alternative conception	1	0
6. Place an X (on the image below) where you would build your home. Why would you build your home there?		
Response patterns		
Away from the river	0	2
Safe from flooding	0	2
Close the river or other bodies of water	6	8
Not in town	1	1
Trees (a few trees → woods)	5	7
Shelter from the wind	1	0
View of trees and mountains	0	1
Room for gardening, farming, or ranching	1	1
Hunting	1	1
Fishing	2	1
Space to play (basketball, swimming, other)	2	5

[1]Pre = preassessment; post = postassessment.

features and their importance in the landscape. Students' exploration sometimes led to a deepening of, rather than a deviation from, the lesson theme. Students who had been exposed to Google Maps at school appeared to be more focused on designated layers and the lesson theme than students who, as a whole, and not been exposed to Google Maps or Google Earth at school.

We additionally noted that students did not automatically explore the different layers provided or naturally move between layers to answer questions posed to them. We thus

TABLE V: Fifth- and Sixth-Grade Responses in Student Evaluation of Digital Earth Lesson.

Questions	Responses	($N = 18$)
Have you seen or used Google Earth before last week's lesson?	Yes	15
	No	3
What did you like best about this lesson?	Seeing local community features (houses, towns)	10
	Seeing local landscape features	5
	Repeat photos	3
What did you like least about this lesson?	Nothing	7
	Poor resolution and slow computer speed	6
	Boring or too much talking	2
	I didn't get to see my house	1
	Seeing roads	1
	Worksheets	1
What confused you about this lesson?	Nothing	14
	Photograph features	1
	Moving from place to place	1
	Photo clarity	1
What would make this more interesting for other students?	Include familiar features (houses, horses, friends)	5
	See more repeat pictures	4
	Show current motion or video	2
	Nothing	2
	Include more historical information	1
	A field trip to swim in Pryor Creek	1
	Use Google Images from today	1
	Anything	1
	Better resolution	1

conclude that a more effective incorporation of digital Earth technology in classrooms might include three to five introductory lessons, including (1) an exploration of Google Earth "basics" prior to focused lessons, which allow students to explore their landscapes and global features using available tools; (2) an introductory lesson on using layers, with particular focus on the way maps and aerial photographs interact to provide information; and (3) focused lessons on a given theme.

Integrating the Local and the Global: Addressing Misconceptions

While digital Earth technology did appear to engage students in science through their knowledge of local landscape, it seemed to both correct and support student misconceptions in science concepts and did not always naturally encourage the integration of global and local scales. For example, during their lesson on landscape change, 5th- and 6th-grade students in the combined classroom were asked to examine a photograph that depicted a nearby valley surrounded by mountains. They were then instructed to describe what the landscape might have looked like 100 y prior. Three students believed that the mountains had changed configuration due to earthquakes and "because of the tectonic plates," and one suggested that weathering and winds changed features. When students were later shown a photograph of the landscape taken 100 y prior alongside the present landscape and given a blank box in which they were asked to draw the landscape 100 y from now, 15 out of 16 students drew mountain configurations similar to those of the current image. In this case, repeat imagery projected on a digital Earth helped them envision more appropriate timescales of geophysical change. Conversely, when 4th and 5th graders were asked to describe the flood event of 2011 using local flood photographs and compressed KML layers of precipitation, students seemed to believe that the floods were just local events, not connected to larger scales or broader patterns in climate and runoff. We concluded that a localized digital Earth tool may facilitate integrated understanding of global and local concepts over time and space; it also may facilitate misconceptions in an understanding of scale.

Professional Development and Future Use

Our teacher cohort had little experience with Google Earth's compressed KML files and aerial imagery prior to this pilot project; teachers sometimes initially found the digital Earth technology intimidating without guidance from our geoscientist. Teachers do not need to feel that digital Earth lessons require support from geoscience professionals. While some of the layers we used required the use of ArcGIS software, many are easily accessible to teachers in their local environment. Historical aerial photographs, for example, are available at no charge online through USGS EarthExplorer;

many local archives provide historical photographs; and Internet links provide hydrological data and visualizations.

The dissemination of digital Earth materials may best take place through professional development of teachers across disciplines and, perhaps most ideally, through an interdisciplinary team of teachers within schools or school districts in a variety of cultural contexts.

CONCLUSION

As a pilot project, the level of student and teacher engagement in the Dynamic Earth program warrants further exploration, additional data collection, and systematic observation. We are particularly interested in two areas of research. First, does digital Earth technology encourage students to (1) recognize the complexity of interacting systems on a constantly changing Earth (National Research Council, 2012) and (2) apply these systems to local challenges that are both environmental and cultural in scope? Second, is a combined use of digital Earth technology and field trips an effective means of encouraging students to develop "cross-cutting concepts" that integrate culture and science?

Students' sense of place is increasingly virtual, even in remote communities with poor cell phone service. Their natural inclination to explore their home digitally makes the digital Earth technology an engaging geoscience classroom tool, particularly when coupling sense of place and science. More importantly, with guided help, it may prepare students to conceptualize complex environmental challenges and recognize humanity's role in them. As the National Resource Council (2012) notes, "Only in the relatively recent past have people begun to recognize the dramatic role humans play as an essentially geological force on the surface of Earth, affecting large-scale conditions and processes." On a digital, multicultural Earth, people and processes are equally dynamic.

Our program, though preliminary, suggests several directions for using digital Earth technology in culturally diverse areas where teachers may have little geotechnical expertise. More effective use of digital Earth technology might include the following:

(1) A community process that more intentionally involves teachers, students, and community members in the development of a localized digital Earth tool
(2) The use of local, visual examples in culturally relevant contexts to convey the complexity of interconnection among the atmosphere, hydrosphere, geosphere, and biosphere (see Core Idea ESS2 in National Research Council, 2012), as well as their relationship to people and place
(3) The use of local natural hazard events depicted on a digital Earth to portray the relationship between humans and Earth systems in local, memorable, contexts (see Core Idea ESS3 in National Research Council, 2012)

Our role in the classroom is to prepare students for the future they will help to create. The geotechnologies allow students to envision a future in which technology and tradition are not dichotomized; land management includes cultural and environmental factors; and many cultures and worldviews are encompassed on one globe.

Acknowledgment

This material is based upon work supported by the National Science Foundation under Grant No. 0634587.

REFERENCES

Aikenhead, G.S. 1997. Toward a First Nations cross-cultural science and technology curriculum. *Science Education,* 81:217–238.

Aikenhead, G.S., and Jegede, O.J. 1999. Cross-cultural science education: A cognitive explanation of a cultural phenomenon. *Journal of Research in Science Teaching,* 36:269–287.

American Geophysical Union. 2002. AGU diversity plan. Available at http://education.agu.org/diversity-programs/agu-diversity-plan/ (accessed 17 August 2012).

Bang, M., Medin, D.L., and Atran, S. 2007. Cultural mosaics and mental models of nature. *Proceedings of the National Academy of Sciences of the USA,* 104:13868–13874.

Basso, K.H. 1996. Wisdom sits in places: Landscape and language among the Western Apache. Albuquerque, NM: University of New Mexico Press.

Bohm, D. 1980. Holism and the implicate order. New York: Routledge.

Bureau of Indian Affairs. 2012. Crow agency. Available at http://www.bia.gov/WhoWeAre/RegionalOffices/RockyMountain/WeAre/Crow/Index.htm (accessed 22 August 2012).

Cajete, G. 2000. Native science: Natural laws of interdependence. Santa Fe, NM: Clear Light Publishers.

Czujko, R., and Nicholson, S. 2012. The Native American presence in physics and the geosciences. American Institute of Physics. Available at http://www.aip.org/statistics/trends/highlite/minority/nativehigh.htm (accessed 15 August 2012).

Deloria, V., and Wildcat, D.R. 2001. Power and place: Indian education in America. Golden, CO: Fulcrum.

Gruenewald, D.A. 2003. Foundations of place: A multidisciplinary framework for place-conscious education. *American Educational Research Journal,* 40:619–654.

Kawagley, A.O. 1995. A Yupiaq worldview: A pathway to ecology and spirit. Prospect Heights, IL: Waveland Press.

Kawagley, A.O. 2001. Tradition and education: The world made seamless again. *In* James, K., ed., Science and Native American communities. Lincoln, NE: University of Nebraska Press, p. 51–56.

Kerski, J.J. 2008. The role of GIS in digital Earth education. *International Journal of Digital Earth,* 1:326–346.

Lee, O. 2003. Equity for linguistically and culturally diverse students in science education: A research agenda. *Teachers College Record,* 105:465–489.

Lee, O.H., and Buxton, C. 2008. Science curriculum and student diversity: A framework for equitable learning opportunities. *Elementary School Journal,* 109:123–137.

Lewis, E.B., and Baker, D.R. 2010. A call for a new geoscience education research agenda. *Journal of Research in Science Teaching,* 47:121–129.

Meinig, D.W. 1979. The beholding eye: Ten versions of the same scene. *In* Meinig, D.W., and Jackson, J.B., eds., The interpretation of ordinary landscapes: Geographical essays, vol. January. New York: Oxford University Press, p. 33–48.

Monet, J., and Greene, T. 2012. Using Google Earth and satellite imagery to foster place-based teaching in an introductory geology course. *Journal of Geoscience Education,* 60:10–20.

National Center for Education Statistics. 2005. Status and trends in the education of American Indians and Alaska Natives. National Center for Education Statistics, U.S. Department of Education.

National Research Council. 2012. A framework for K–12 science education. Washington, DC: National Academies Press.

Natural Resource Information System. 2011. Land ownership in Montana counties, state of Montana. Available at https://nris.mt.gov/montanafacts/county_own.asp (accessed 22 August 2012).

Office of Public Instruction. 2010. Montana American Indian student achievement data report. Helena, MT: Office of Public Instruction.

Peat, F.D. 2002. Blackfoot physics. Grand Rapids, MI: Phanes Press.

Riggs, E.M. 2005. Field-based education and indigenous knowledge: Essential components of geoscience education for Native American communities. *Science Education,* 89:296–313.

Ryden, K.C. 1993. Mapping the invisible landscape: Folklore, writing, and the sense of place. Iowa City, IA: University of Iowa Press.

Schultz, R.B., Kerski, J.J., and Patterson, T.C. 2008. The use of virtual globes as a spatial teaching tool with suggestions for metadata standards. *Journal of Geography,* 107:27–34.

Semken, S. 2005. Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates. *Journal of Geoscience Education,* 53:149–157.

Semken, S., and Brandt, E. 2010. Implications of sense of place and place-based education for ecological integrity and cultural sustainability in diverse places. *In* Tippins, D.J., Mueller, M.P., van Eijck, M., and Adams, J.D., eds., The confluence of ecojustice, place-based (science) education, and indigenous knowledge systems. New York: Springer, p. 287–302.

Semken, S., Neakrase, J., and Dial, R.E. 2009. Factors that influence sense of place as a learning outcome and assessment measure of place-based geoscience teaching. *Electronic Journal of Science Education,* 13:136–159.

Taylor, M.C. 2009. End the university as we know it, op-ed. *New York Times,* April 27.

Tuan, Y.F. 1974. Topophilia: A study of environmental perception, attitudes, and values. Englewood Cliffs, NJ: Prentice Hall.

U.S. Census Bureau. 2011. State and county QuickFacts, Montana. Available at http://quickfacts.census.gov/qfd/states/30000.html (accessed 14 August 2012).

van der Hoeven Kraft, K.J., Srogi, L., Husman, J., Semken, S., and Fuhrman, M. 2011. Engaging students to learn through the affective doma: A new framework for teaching in the geosciences. *Journal of Geoscience Education,* 59:71–84.

Warren, B., Ballenger, C., Ogonowski, M., Rosebery, A.S., and Hudicourt-Barnes, J. 2001. Rethinking diversity in learning science: The logic of everyday sense-making. *Journal of Research in Science Teaching,* 38:529–552.

Wyckoff, W. 1999. Creating Colorado: The making of a Western American landscape, 1860–1940. New Haven, CT: Yale University Press.