COGNITIVE AND AFFECTIVE OUTCOMES OF A SOUTHWEST PLACE-BASED APPROACH TO TEACHING INTRODUCTORY GEOSCIENCE

The physical and cultural landscapes of the Southwest United States epitomize places, which are localities imbued with meaning by human experience. Sense of place comprises the meanings of and emotional attachments to places held by individuals or groups, and thus bridges cognition and affect. Place-based teaching deliberately engages and leverages the sense of place of students and instructor with experiential, cross-cultural, interdisciplinary content and methods that may better engage underrepresented students with rich culturally-rooted senses of place, such as American Indians and Mexican Americans in the Southwest. We propose that psychometric measurement of the cognitive and affective components of sense of place, place meaning and place attachment, can be used to test the effectiveness of place-based teaching. A Southwest-based undergraduate geoscience course, which presented basic concepts in the context of familiar regional places and the cultural knowledge of these places, was piloted for a diverse class of 31 students in fall 2005. Cognitive and affective outcomes were assessed with valid and reliable surveys of place attachment, place meaning, and geoscience content knowledge. The gains were analyzed with non-directional dependent samples t-tests. Student mean place attachment to Arizona increased significantly, $t(26) = 2.94$, $p < 0.01$, from near-indifference to positive attachment, and the post-course mean place attachment was greater than that for students enrolled in conventional geoscience courses. Mean place meaning of Arizona increased significantly, $t(26) = 7.17$, $p < 0.01$; students developed richer and more diverse understanding of the region. General geoscience content knowledge, measured using the Geoscience Content Inventory, increased significantly, $t(26) = 4.19$, $p < 0.01$. The students began the place-based course with content knowledge equivalent to that of their peers nationwide, but their mean post-course score was above the national mean. We conclude that place-based teaching can be assessed both cognitively and affectively. The positive outcomes of this experimental course, and the cultural and personal relevance inherent in the method, suggest that place-based geoscience teaching is particularly appropriate for use in naturally and culturally diverse settings.

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Introduction

This study was conducted as part of a broad project to enhance introductory science and mathematics courses for pre-service and in-service teachers under a Mathematics-Science Partnership funded by the National Science Foundation. Many participating regional schools serve diverse and underrepresented student populations, and enhanced retention of such students in science and mathematics courses is an important goal of the Partnership.

Place, Sense of Place, and Place-Based Teaching

Place has been defined as any locality or space that has become imbued with meaning by direct or indirect human experience in it or with it (Tuan, 1977). The naturally and culturally rich landscapes of Arizona and surrounding parts of the Southwest United States epitomize places. The diverse meanings (aesthetic, ceremonial, economic, scientific, spiritual, etc.) that places hold for people, and the emotional attachments that people develop for meaningful places, comprise the sense of place (Relph, 1976; Brandenburg & Carroll, 1995), which thus bridges cognition and affect.

Indigenous American Indian and long-rooted Mexican-American communities in the Southwest possess rich, culturally-based senses of place (Basso, 1996; Cajete, 2000; Alarcón, 2002). Though personally and communally tied to land and environment, they have historically been underrepresented in geoscience and other natural sciences (Riggs & Semken, 2001). Teaching that contradicts or minimizes sense of place may be one of many factors that deter these students from scientific study and careers (Kawagley, D. Norris-Tull, & R.A. Norris-Tull, 1998; Aikenhead & Jegede, 1999; Semken, 2005). This may be especially relevant for geoscience, which probe into, and offer very definite physical interpretations of, culturally and personally meaningful physical places.

Place-based (PB) or place-conscious teaching is a situated approach that deliberately engages and leverages the senses of place of students and instructor, through experiential immersion in local places or case studies, and synthesis of cross-cultural and cross-disciplinary knowledge of places (Gruenewald, 2003; Sobel, 2004; Semken, 2005). Hence, PB teaching endorses ties between students and their homeland, models respect for the cultures and values of the local population, and is relevant and engaging. PB teaching has been recommended to improve engagement and retention of students from indigenous or historically rooted communities (Cajete, 2000; Riggs, 2004; Chinn, 2006).

As PB teaching and learning are intended to engage and leverage the sense of place, we propose that sense of place should and can be used to measure and test the effectiveness of the method. Sense of place is now regularly factored into land-use planning and regulation (Williams & Stewart, 1998) and architectural design (Bott, Banning, Wells, Haas, & Lakey, 2006), and environmental psychologists have devised and validated quantitative instruments to measure its two principal components, place attachment (Shamai, 1991; Williams & Vaske, 2003) and place meaning (Young, 1999).

In this study we used a valid and reliable survey of place attachment developed by Williams and Vaske (2003), referred to here as the Place Attachment Inventory; and a valid and reliable survey of place meaning by Young (1999), referred to as the Place Meaning Survey. These were administered in concert with a valid and reliable survey of general geoscience content knowledge (the Geoscience Content Inventory; Libarkin &

Anderson, 2005; 2006a; 2006b). These three instruments were used in a preliminary assessment of cognitive (place meaning and content knowledge) and affective (place attachment) of an experimental Southwest-based introductory undergraduate geoscience course (Geology101sw) during the fall semester 2005 at Arizona State University (ASU).

Our research objectives were: (1) to determine if statistically significant changes in place attachment and place meaning can be measured; (2) assess the effects of PB teaching on the sense of place in a diverse group of ASU undergraduate students, including some who hail from outside the Southwest; and (3) compare geoscience content learning in Geology101sw with learning that would accrue from a more conventional introductory course. In this preliminary study, it was only logistically possible to offer one section of the course, so control groups were not available.

Course Design and Implementation

The Geology101sw course was intended to serve as a Southwestern place-based alternative to the general large-enrollment physical-geology lecture course offered regularly at ASU (n ~ 220 per section) and similar universities. Therefore, the course differed from its mainstream equivalent primarily in content and organization rather than instructional methods. One semester-long section of Geology101sw was offered in three fifty-minute interactive lecture classes on campus and two half-day weekend field trips in the Tempe area, but bolstered by considerable Southwest-based online content, including landscape flyovers and other visualizations. The content was presented in eight modules that addressed different aspects of geology, climate, and environmental quality, all specifically relevant to the Southwest, and presented in the context of specific Southwestern places and cultural knowledge of these places. Table 1 provides a modular outline of the course.

Table 1

Modules Presented in the Fall 2005 Geology 101sw Course

Module	Place(s)	Topics
A sense of the Southwest	Synoptic Southwest	Regional physiography, variations in climate and resources; land use; cultural landscapes and place names
Earth from the Southwest	Navajo and San Carlos Apache nations, Grand Canyon, Arizona mining districts	Imaging the deep structure of the Earth from a local vantage point; cultural perspectives on the Earth's interior
Building blocks of the Southwest	Grand Canyon, Mogollon Rim, Arizona mining districts	Rocks and minerals encountered in the region; mining history; indigenous and modern use of Southwest gemstones

It's a deep heat	San Francisco, Sunset Crater, Hopi, Navajo, and San Carlos volcanoes, AZ; Ship Rock, NM; Paricutín, Mexico	Volcanoes of the Southwest; volcanic landmarks; potential volcanic hazards; Indigenous stories of regional volcanic activity
How the Southwest is shaped	Synoptic Southwest	Origin of Southwest mountain ranges; metamorphic rocks; earthquakes; earthquake potential in the Southwest
How the Southwest is sculpted	Monument Valley; Petrified Forest; Salt River valley, AZ	Weathering and erosion; soil formation and soil erosion in deserts; landslide hazards
Layers in the landscape	Colorado Plateau of northeastern Arizona; Four Corners coal mines and power plants	Sedimentary systems, sedimentary environments; fossils; origin, use, and environmental impact of petroleum and coal
Water beneath the desert	Groundwater basins of central and southern Arizona	Ground water systems, resources, and quality; fissures and subsidence hazards in Arizona
Streams across the desert	Salt and Colorado River systems in Arizona; Lake Powell; Glen Canyon Dam; San Juan River canyons	Fluvial processes and geology; water projects and use in the Southwest; American Indian versus non-Indian water rights
Work of the wind	Yuma dunefields, AZ; Death Valley; Canyon de Chelly and Monument Valley, AZ	Eolian geologic processes; windblown sand in the geologic record; dust storms and hazards in the Southwest
What makes a desert	Sonoran, Mojave, and Chihuahuan deserts; Colorado Plateau semi-desert	Causes of the Southwest's dry climate; synthesis of processes that shape desert landscapes
When Sky strikes Earth	Meteor Crater, AZ; comparisons with other planetary surfaces	Impact cratering as a geologic process; origin of the Solar System; American Indian sky knowledge in the Southwest

This organizational scheme is consciously based on an ethnogeologic model of duality in nature from the traditional knowledge of the Diné (Navajo) people (Semken & Morgan, 1997; Semken, 2005), which describes natural processes of change as interactions between a dynamic Earth and Sky (Nohosdzáán and Yádilhil in the Diné language; Semken & Morgan, 1997; Blackhorse, Semken, & Charley, 2003). The module sequence is a cyclical intellectual path from the surface through the solid Earth, to Sky interactions with Earth, and finally to fluid-Earth and extraterrestrial (Sky) processes. This curriculum design, first used at the Diné tribal college in the 1990s (Semken, 2005); was adapted for a more diverse student audience at ASU through the study of places, processes, and cultural elements more broadly representative of Arizona and the Southwest. The meaning and purpose of the design were explained to the participating students early in the course.

The fall 2005 Geology101sw course made liberal use of relevant case studies as examples and points of class discussion; these included the legacy of Cold War-era uranium mining on the Colorado Plateau, coal-fired power plants in the Four Corners area that export electricity to the major population centers of the Southwest, copper-mining booms and busts in Arizona, control and overuse of the Colorado River system, and the impacts of an ongoing, multi-year regional drought on soils, landforms, and water resources.

Thirty-one students were randomly selected from a list of volunteers: 13 female and 17 male; 2 American Indian, 1 Pacific Islander, 3 Hispanic, and 26 White. Prior to the course, the students were informed that it would be experimental and require participation in surveys. They were not specifically informed about the place-based design of the course until after the pre-tests were administered.

Data Collection

Four valid and reliable surveys of different cognitive and affective outcomes were administered as pre-tests and post-tests, at the start of the first day of class and on the final day. For the surveys of place attachment and place meaning, the place named was "Arizona," as the term "Southwest," which the students would encounter in the pre-test before it was explained in the first class, was considered to be more vague. Although 31 students originally registered for the course, 4 dropped out at different points in the semester, so 27 students took both the pre-tests and the post-tests.

Place Attachment

Place attachment describes an emotional bond formed through direct experience in, or other engagement with (e.g., through books or films) a place. Shamai (1991) and Kaltenborn (1998) demonstrated that place attachment can be measured quantitatively. Williams and Vaske (2003) developed a valid and reliable 12-item, 5-point Likert-scale place-attachment survey, initially used in recreational places but generalizable to other settings. The items (Table 2) were adapted verbatim (except for the selection of place) for this experiment, in a survey now referred to as the Place Attachment Inventory (PAI; Semken & Piburn, 2004).

Table 2

Place Attachment Inventory

1. I feel that this place is a part of me.
2. This place is the best place for what I like to do.

3. This place is very special to me.
4. No other place can compare to this place.
5. I identify strongly with this place.
6. I get more satisfaction out of being at this place than at any other.
7. I am very attached to this place.
8. Doing what I do at this place is more important to me than doing it in any other place.
9. Being at this place says a lot about who I am.
10. I wouldn't substitute any other area for doing the types of things I do at this place.
11. This place means a lot to me.
12. The things I do at this place I would enjoy doing just as much at a similar site.

These statements were rated on a five-point Likert scale with 1 corresponding to "strongly disagree," 2 to "disagree," 3 to "neutral," 4 to "agree," and 5 to "strongly agree." Therefore, a total PAI score below 36 indicates negative place attachment, and a score above 36 indicates positive place attachment.

Place Meaning

Place meaning is far more specific to a given place and thus more difficult to measure. No survey of place meaning specific to the Southwest United States currently exists. A validated quantitative survey of place meaning developed for a scenic rural and park region of northeastern Australia (Young, 1999) was adapted for this study, as most of the items surveyed were directly relevant to Arizona and the Southwest. One item, "Important for Aboriginal culture," was changed to "Important for Native American culture." Three place meanings from the Young (1999) survey (tropical, fun, and comfortable) were not used. The 28 survey items used in this study, collectively referred to as the Place Meaning Survey (PMS), are given in Table 3.

Table 3

Place Meaning Survey

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1. Ecologically important
2. Important to preserve
3. Educational
4. Unique
5. Scientifically important
6. Fragile
7. Interesting

8. A privilege to visit
9. A privilege to live here
10. Tranquil
11. Scenic
12. Relaxing
13. Wilderness
14. Beautiful
15. Exotic
16. Remote
17. Unspoiled
18. Authentic
19. Adventurous
20. Unusual
21. Important for Native American culture
22. Historical
23. Ancient
24. Spiritually valuable
25. Overdeveloped
26. Dangerous
27. Crowded
28. Threatened

Respondents rated these statements on a five-point Likert scale identical to that used for the PAI, with 1 corresponding to "strongly disagree" and 5 to "strongly agree." Strongest agreement with the first 23 items indicates that Arizona holds that particular affirmative place meaning for the respondent. The opposite was held to be true for the final four items, which represent degradation of Arizona. These items were reverse scored. Therefore, the minimum PMS score of 27 indicates that Arizona holds very little meaning for the respondent and a score approaching the maximum of 140 indicates that Arizona holds rich and diverse meanings for the respondent.

Geoscience Content Knowledge

At the undergraduate level, the effectiveness of PB teaching in improving the geoscience content knowledge of students has not been evaluated (Semken, 2005). The syllabus of a PB course is focused on locally relevant subject matter, meaning that there is less "coverage" of geoscience topics overall. We predict that a PB approach, in which direct engagement with familiar and meaningful places creates cognitive and affective scaffolding for learning geoscience principles, should be no less effective than general survey courses in imparting geoscience content knowledge.

The valid and reliable Geoscience Content Inventory (GCI) of Libarkin and Anderson (2005, 2006a) was used to measure changes in the geoscience content knowledge of students in Geology101sw. The GCI tests understanding of fundamental concepts in geology and related concepts in physics and chemistry of the Earth. It can be used not only to measure gain during a course such as Geology101sw, but to compare that gain to a national baseline established from GCI measurements in 32 diverse institutions nationwide (n = 930; Libarkin & Anderson, 2005).

The GCI consists of a 73-item test bank validated by analytical techniques including item response theory (Rasch analysis) and classical test theory (Libarkin & Anderson, 2005). For this study, a subtest (Table 3) consisting of 15 items chosen to correspond as closely as possible to the topics presented in Geology101sw, was assembled from a list of validated item combinations obtained from Libarkin and Anderson (2006b).

Table 3

Geoscience Content Inventory Subtest Items Used in This Study

GCI Item Number	Topic
1	What techniques are used to determine the age of Earth
2	What greatly affects erosion rates
6	Best definition of a tectonic plate
7	Surface of Earth at its formation
16	Age of oceanic versus continental rocks
20	Internal structure of Earth
30	Compare old and young mountains
36	Coexistence of humans and dinosaurs?
37	Time scale for supercontinent breakup
40	Which things can become fossils
51	Relationship among volcanoes, earthquakes, and tectonic plates
59	What is groundwater
65	How do ocean basins form
68	About how long ago did Earth form
73	How did supercontinent break up

Findings and Interpretations

The results of the pre- and post-course surveys are presented in Tables 4, 5, and 6.

Place Attachment

Table 4

Comparison of Pre- and Post-Test PAI (Place Attachment to Arizona) Mean Scores for Students from Geology101sw and from Non-Place-Based Lecture Courses

Pre-test mean for Geology101sw students with matching post-test (n = 27)	37.9 ± 8.7
Post-test mean for Geology101sw students with matching pre-test (n = 27)	41.4 ± 9.0
End-of-course mean for ASU students in non-PB lecture course (n = 753; Perkins & Semken, unpublished data)	35 ± 9

As discussed above, a PAI score of 37 to 60 indicates positive place attachment. Based on a non-directional dependent samples t-test, we reject the null hypothesis of no population mean differences, $t(26) = 2.94$, $p < 0.01$. We conclude that there is a significant difference in the students' place attachment to Arizona before the PB course (Mean = 1.74, SD = 9.01) and their place attachment to Arizona afterward (Mean = 1.68, SD = 8.74). We are 95% confident that the interval 1.06 to 5.98 contains the true population mean difference. The correlation was 0.76. The results indicate that student place attachment to Arizona increased from near-indifference to positive attachment. The post-test mean place attachment to Arizona for Geology101sw students is greater than that measured for ASU students (n = 753) enrolled in the conventional geoscience lecture course on the same general topics.

Place Meaning

Table 5

Comparison of Pre- and Post-Test PMS (Place Meaning of Arizona) Mean Scores for Geology101sw Students

Pre-test mean for Geology101sw students with matching post-test (n = 27)	101.5 ± 11.3
Post-test mean for Geology101sw students with matching pre-test (n = 27)	114.7 ± 9.6

The maximum possible score is 140. Based on a non-directional dependent samples t-test, we reject the null hypothesis of no population mean differences, $t(26) = 7.169$, $p < 0.01$. We conclude that there is a significant difference in strength of place meaning of Arizona for students before Geology101sw (Mean = 1.84, SD = 9.58) and their strength of place meaning for Arizona afterward (Mean = 2.17, SD = 11.27). We are 95% confident that the interval 9.38 to 16.92 contains the true population mean difference. The correlation was 0.59. The results indicate that Geology101sw students developed richer and more diverse understanding of Arizona as a place during the place-based course.

Geoscience Content Knowledge

Mean scores from the pre-course and post-course GCI subtests were compared to each other and to national baseline mean GCI scores. Because the national means are calculated from the results of a range of different GCI subtests of varying difficulty, it was first necessary to convert raw GCI scores (R_{GCI}) on a scale of 1 to 15 points to scaled percentage scores (S_{GCI}), using a formula provided by Libarkin and Anderson (2006a):

$$S_{GCI} = 16.76 + 4.30R_{GCI} + 0.115(R_{GCI}-7.5)^2 + 0.042(R_{GCI} - 7.5)^3 - 0.0017(R_{GCI} - 7.5)^4$$

The scaled mean scores are presented for comparison in Table 6.

Table 6

Comparison of Pre- and Post-Test Scaled GCI Mean Scores (S_{GCI}) for Geology101sw Students and for Introductory Geology Students Nationwide

	Geology101sw students (n = 27)	Students nationwide (n = 930; Libarkin & Anderson, 2005)
Pre-test Mean S_{GCI} for students with matching post-test	41.8 ± 13%	43 ± 11%
Post-test Mean S_{GCI} for students with matching pre-test	58.76 ± 15%	47 ± 12%

Based on a non-directional dependent samples t-test, we reject the null hypothesis of no population mean differences, $t(26) = 4.19$, $p < 0.01$. We conclude that there is a significant difference in the students' geological content knowledge before the place-based course (Mean = 2.42, SD = 12.56) and their geological content knowledge afterward (Mean = 2.56, SD = 13.31). We are 95% confident that the interval 4.96 to 14.49 contains the true population mean difference. The correlation was 0.57. Comparison of our results with those published by Libarkin and Anderson (2005) indicate that Geology101sw students began the course at a level equivalent to that of students nationwide, but most of them finished with a significantly improved conceptual understanding of geoscience, even when compared to their peers nationwide.

Discussion

Our results demonstrate that statistically significant changes in the two principal components of sense of place, place attachment and place meaning, can be measured using published validated psychometric surveys. These factors can and should be used to evaluate the effectiveness of PB teaching. Our results also strongly suggest that the place-based Geology101sw course effectively enhanced student place attachment and place meaning, and improved student geoscience content knowledge at least as effectively as non-PB mainstream courses. This, considered with the local and cultural relevance of the approach, would recommend it for use in naturally and culturally diverse regions such as the Southwest United States. However, as our findings were subjected to limited baseline comparison and because a controlled study was not possible, other factors such as instructor passion and above-average skills in the self-selected volunteer student group cannot be ruled out. Place-based geoscience teaching merits continued study in larger controlled experiments.

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