Casey D. Allen tied for First Place in *RGE's* Early Career Scholar Paper Competition. His winning paper is below.

Concept Mapping Validates Fieldwork's Capacity to Deepen Students' Cognitive Linkages of Complex Processes

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Abstract

Concept maps created by introductory physical geography students were analyzed to assess the power of a field index in students learning concepts related to rock decay. Students (n = 571) were randomly selected from introductory physical geography laboratory sessions where 86% had never taken another college-level geography course, 46% had never taken a "lab science" course, and 22% were from minority (non-white) populations. All students, upon completing a straight-forward demographic survey and open-ended questionnaire, undertook a concept mapping exercise after learning about rock decay through direct instruction (i.e., lecture). From this n, 322 students also took part in a hands-on field-based experience involving analyses of rock decay associated with petroglyphs, and then completed another concept map. Concept map scores indicate field experience participants understood form and process connections better after the field experience than after direct instruction, and especially minority students, where the average score increase approached 23%, compared to 11% in non-minorities. Female students (16% average increase) also scored higher after the field experience compared to male students (11% average increase). Concept maps were compared to open-ended questionnaires to further establish validity, and after testing for normalcy with Kolmogorov-Smirnov, *t*-tests revealed all score increases to be highly statistically significant ($p < 0.001$), with minority student score increases compared to non-minority increases yielding a statistical significance ($p < 0.01$), while learning in females over males yielded a statistical trend ($p = 0.067$). These findings reveal fieldwork's power to deepen cognitive linkages between complex biophysical processes and the corresponding landscape forms, especially among minority and female students.

Keywords: Field methods, concept mapping, alternative pedagogy, geography education, science education assessment

Introduction

Students engaged in science and science-related curricula often rely on basic, rote learning strategy: repeating back to the instructor what they just "learned" in laboratory-format exercises and then, often quickly, forgetting that "learning" (Hsu & Hsieh, 2005; Regan-Smith et al., 1994). As educational researchers suggest, however (cf. Fardanesh, 2002; Hsu & Hsieh, 2005; Mayer, 2002), effective pedagogy includes both qualitative *and* quantitative components and always revolves around meaningful learning, especially if the desired outcome is an authentic research experience (Herrington, Oliver, & Reeves, 2009). Thus, when students understand how to assemble, manage, and assimilate knowledge into a system, a dynamic learning environment results. Concept maps represent an effective method for achieving this goal (Daley, Shaw, Balistrieri, Glasenapp, & Piacentine, 1999; Edwards & Fraser, 1983; Guastello, Beasley, & Sinatra, 2000; Novak, 1990; Novak & Canas, 2008; Ruiz-Primo & Shavelson, 1996; Van Zele, Lenaerts, & Wieme, 2004).

Used for years in the biomedical and life sciences disciplines, concept mapping breathes new life into science education (Kinchin, 2005; Kinchin & Hay, 2005; Kinchin, Hay, & Adams, 2000; Stoddart, Abrams, Gasper, & Canaday, 2000; Van Zele et al., 2004). Yet rarely are concept maps used in any capacity to aid environmental or Earth science education (including physical geography), even though these disciplines remain filled with complex topics. This paper uses concept mapping to assess whether short, intense field experiences (using rock decay as a core component) can promote deep learning in introductory physical geography students. The specific field tool used, the Rock Art Stability Index (RASI, see Cerveny, 2005 & Dorn et al., 2008), asks students to combine environmental studies — biophysical processes of rock decay — with environmental perception (a humanistic endeavor), creating a unique window for viewing how people perceive connections between resultant forms and their processes.

Following a review of the study context, I outline the methods for this study which contain brief specificities on concept map assessment (scoring), population selection, training formats, quantitative techniques used, an explanation of how RASI was used in the training process, and secondary data collected to corroborate concept map scoring. Results are then discussed, with special attention paid to minority (non-white) and female student scores, average concept map scores, and comparative concept map scores between laboratory sessions, including an analysis of students' changed perceptions about rock art management.

Study Context

A vital concern to communities in the arid western United States lies in the conundrum of providing access to public lands, and at the same time managing the priceless heritage of rock art (i.e., petroglyphs) being destroyed daily by natural and anthropogenic processes (Whitley, 2005). The goal of this research rests in assessing whether students' science education can be improved by engaging them in field research that ultimately leads to better management of this priceless, socially-relevant cultural heritage resource. As results show, after a single field experience assessing rock art, student views on rock art management change dramatically (*Results and Discussion*). Further, managing rock art is an inherently interdisciplinary environmental science endeavor interfacing with social science (archaeology) and natural science (physical geography, physical geology, plant biology), among other disciplines (engineering, art, aesthetics, etc.) (Pope, Meierding, & Paradise, 2002).

To aid in the triage of rock art management, the Rock Art Stability Index (RASI), was created to synthesize identification of weathering (i.e., rock decay) elements into a field-based tool that assesses the stability of joint faces (or panels) hosting the art. Unlike other rock art assessment methods (Fitzner, 2002; Viles et al., 1997), RASI was created as a non-invasive, cost-effective field assessment technique focusing on approximately three-dozen easily-identifiable elements, offering an efficient method to help rock art researchers establish the condition of a panel (Cerveny, 2005; Dorn et al., 2008). While still scientifically rigorous enough to yield valid scientific results, RASI also remains available to the amateur (Dorn et al., 2008), and has also been shown to be a replicable tool for rock art assessment (Cerveny, 2005; Cerveny, Dorn, Gordon, & Whitley, 2006; Dorn et al., 2008). Thus, I hypothesized that, because of its inherent linkages, RASI could be used as an effective means to engage students in what is a traditionally stale, yet very important science topic: weathering (rock decay).

Owing to its wide use and applicability in the sciences, weathering is arguably one of the most basic and important (yet misunderstood) science concepts. Yet, while weathering is taught in many disciplines, it receives unequal treatment. In physical geography, weathering is nearly always related to form and process, or the breaking down of rock (Christopherson, 2005; McKnight & Hess, 2007); in geology texts, process (not form) is the key driving force behind changing "...the physical and chemical character of rock at or near Earth's surface" (Plummer, McGeary, & Carlson, 2003, p. 104). Environmental and soil scientists describe weathering in relation to soil formation and process in their introductory texts (Berg & Hager, 2007; Brady & Weil, 2008; Wright, 2008), while beginning archeological texts promote weathering in the context of artifact and "bone" decomposition (Byers, 2008, p. 149-150, p. 397-399). Chemistry texts focus on weathering's relation to molecular arrangement in a liquid (e.g., water (Bauer, Birk, & Marks, 2007)), while geochemistry books assess mineral composition in a laboratory setting (Brantley & Chen, 1995; Bullen, White, Blum, Harden, & Schulz, 1997; Suarez & Wood, 1996). As this research demonstrates, however, when taught through the socially-relevant issue of rock art using a field-based technique, weathering comes alive for students—regardless of previous disciplinary background knowledge and/or experience. Further, because of this hands-on, field training method, students demonstrated deeper understanding of connections between the form(s) and process(es), while also gaining an appreciation for rock art, as evinced by their increase in concept map scores and revealing open-ended questionnaires.

Methods

With institutional review board (human subjects) approval, introductory physical geography students completed both lecture and laboratory experiences that included the subject of weathering. Students selected for this study had already learned weathering as traditionally taught by in-class lecture, but had yet to complete the weathering-related laboratory portion. This study utilized two-and-a-quarter regular, three-hour laboratory sessions over a three-week period that included a pre-RASI training concept map and simple open-ended questionnaire, a hands-on field experience involving RASI, and a post-RASI training assessment consisting of another concept map and the same open-ended questionnaire. Each concept map and questionnaire was identified by students' first and last initials, which could then be tracked against demographic data collected during the first session.

Population and Site Selection

Overall, a total of 571 students were assessed for this study, all of whom were part of 19 separate laboratory sections in a college-level *Introductory Physical Geography* course, and selected based on completion of the courses' lecture portion dedicated to weathering. Further, because weathering instruction varies depending on familiarity and comfort level (Dove, 1997), 249 of the 571 students were randomly selected to complete the concept mapping exercise after learning basic weathering science through direct instruction (i.e., lecture) *only*, to remove any bias — that is, not all study group participants came *only* from those instructors who discuss weathering in detail during lecture. The remaining 322 college-level students completed both pre- and post-RASI training concept maps and pre- and post-RASI training open-ended questionnaires where just over 86% had never taken another college-level geography course, approximately 46% had never taken a "lab science" course, and nearly 25% were from minority (non-white) populations (as assessed through a demographic survey given to participants).

The field experience involved an onsite visit to a locally-known rock art panel, a short walk from campus. The site was chosen for its easy access, close proximity, and use by previous classes that helped establish RASI as a legitimate field tool (see Cerveny, 2005).

Training Formats

For the purpose of this study, RASI served as an interface to assess how well students understand the connections between weathering form and process *and* how their perceptions of rock art changed after the field-based experience. After completing the weathering portion of the *Introductory Physical Geography* lecture, students were trained over two sessions: one in-class and one in the field. The in-class session began with a simple bubble sheet survey to gather demographic data, followed by a 10-minute PowerPoint introduction to different rock art types and concept mapping. In this presentation, the four basic types of rock art (i.e., petroglyph, pictograph, geoglyph, intaglio (Whitley, 2001)) were shown with textbook-example images so students had a sense of what to expect in the field. The introductory concept map portion covered form, function, and uses, replete with several different examples. Immediately following this introduction, students were given three-minutes to complete a concept map based on the statement, "How natural environmental pressures affect weathering of stone." After collecting the concept maps, students were then given a simple, five-question open-ended questionnaire examining their perceptions of rock art, which could also be used as a comparison to weathering form and process connections made on their concept maps. Students were then formally trained in RASI, which included a passive 10-minute PowerPoint presentation on indices to gain an understanding of why they are utilized in science. In-class training of RASI included a photo-rich PowerPoint presentation followed by several images of rock art panel sections, allowing students guided practice to apply their weathering knowledge. Following this practice, students were shown an image of a local rock art panel in its entirety, given a RASI score sheet, and worked in small groups to complete an actual assessment based on the image provided. Once in-class training was complete, students were briefed on basic field protocols and given the time and location of the next session.

The following week, students met at a local rock art site for their field-based experience, were given RASI score sheets, and instructed to assess the rock art panel. While the researcher was present to clarify misconceptions and answer training-related questions, students were encouraged to collaborate and use each other as resources. Sharing of index rankings, however, was not allowed. This training approach, common in fieldwork settings, coincides with established learner-centered education strategies (McCombs, 2002; Pierce & Kalkman, 2003; Walczyk, Ramsey, & Zha, 2007). Once students completed the RASI, I reviewed it for completeness (to make certain students had not entered data at random) and collected it.

Back in the laboratory the following week, students were again asked to create a concept map based on the statement, "How various natural environmental pressures affect weathering of stone." The same three-minute time limit applied in the post-RASI training concept map creation. Concept maps were then collected, and the same open-ended questionnaires distributed, completed by students, and collected by the researcher.

Concept Map Basics and Scoring

Concept maps serve several purposes in learning assessment. At their most basic level, they help teachers understand how students organize complex ideas into a manageable, graphically-represented system focused on a specific topic (All, Huycke, & Fisher, 2003). At a more complex level, improvement in concept map scores occurs in as little as two attempts, allowing for more focused topical discussion while endeavoring to discover student misunderstanding and promoting higher order thinking skills (Hsu & Hsieh, 2005). In addition, concept maps allow students to quickly arrange their thoughts into an hierarchical system capable of displaying a highly complex topic (Hoffman, Trott, & Neely, 2002). By designing a concept map then, students are not only exposed to right-brain, creative processes that stimulate higher order thinking skills (Hsu & Hsieh, 2005; Schunk, 2000), but quickly become deft at crafting and connecting concepts into a visible array that remains theoretically consistent (Hsu & Hsieh, 2005).

Further, as Kinchin et al. (2000) discovered, concept maps can also be used to examine student improvement in understanding difficult concepts, even in short time spans (cf. Ruiz-Primo & Shavelson, 1996). In hands-on scientific investigations, creating concept maps in short time spans is especially important (Ruiz-Primo & Shavelson, 1996, p. 596). More specifically, concept maps were chosen as an assessment technique for this study because they constitute a valid way to quickly assess higher order thinking skills associated with learning complex biophysical processes in the classroom and after field experiences (Lawless, Smee, & O'Shea, 1998), and lend themselves well to humanistic endeavors (Allen & Lukinbeal, 2011).

Concept map scoring involves assigning a value to valid propositions, examples, crosslinks, and hierarchical structures (Novak & Gowin, 1984). A pre-determined scoring rubric was created for this assessment by the author, modeled after Hsu and Hsieh (2005), West et al. (2002), and Stoddart et al. (2000), and resulted in a maximum possible score of 30. Since nearly every student had never before completed concept maps (as assessed informally via formative assessment), a high priority was placed on correctly identifying the concept (e.g., "rock weathering," "stone weathering," maximum of five points) from the larger statement (i.e., "How natural environmental pressures affect weathering of stone.") Likewise, because the focus of this study rests in students connecting weathering form to process, the ability to understand weathering as it relates to rock art was scored by identifying the number of valid examples (maximum of 10 points). Since concept maps promote systematization, scoring of hierarchies used a sliding scale: first-level hierarchies (maximum of three points); second-level hierarchies (maximum of three points); and third-level hierarchies (maximum of three points). Another essential component in creating concept maps is crosslinks (Jacobs-Lawson & Hershey, 2002). For this study, the ability to make concept and example linkages was used to validate connections between weathering form and process (maximum of six points).

Although subjectivity can occur in concept map scoring, a strict scoring rubric focusing on weathering form and process terminology was followed. To remove research bias further, all concept maps were scored without knowledge of demographic factors because students were identified by a unique student ID code (first and last initial). In the rare case that two or more students shared the same first and last initials in a specific lab session, pre- and post-RASI training concept maps (and open-ended questionnaires) were matched according to handwriting.

Open-ended Questionnaires

To independently validate concept map scoring, and to help minimize bias, data collection also involved a simple open-ended questionnaire. This questionnaire asked students to identify weathering forms and processes they saw as important, as well as how they "felt" about rock art. Thus:

1. What are factors that can help determine rock art stability?
2. Of the factors you listed above, which do you think is/are *the most* important for helping determine rock art stability?
3. What evidence could you give at a rock art site to show that the factors you listed above influence the stability of it?
4. Do these factors *work together* to influence rock art stability? If so, how?
5. Do you agree that rock art should be preserved? Why or why not?

Common responses were then collated into a representative sample of student reflections — both in the pre-RASI training and the post-RASI training laboratory sessions — where the questionnaire was given immediately following the concept map exercise each time. Almost without fail, student answers from the *pre*-RASI training open-ended questionnaire yielded uninformed and mixed results. Bearing in mind students had received weathering in only a direct-teach situation, this was no surprise. As the *Results and Discussion* section (below) explains, however, on the *post*-RASI training open-ended questionnaire and concept maps, students invariably connected form and process *and* agreed to the need for rock art preservation.

Results and Discussion

Statistical Testing and Analysis

In order to obtain a different way of understanding the qualitative signal, I turn to statistical analysis to test the significance of the concept maps. Data followed a normal distribution as revealed from a standard Kolmogorov-Smirnov test of normalcy (Burt & Barber, 1996; Chakravarti, Laha, & Roy, 1967). These students were first taught basic weathering concepts in a lecture setting (*Direct*, in bullet list below, meaning passive, direct instruction), and then learned about weathering through active learning in a field setting using RASI (*RASI*, in bullet list below, meaning learning through this index in a field setting). Paired, one-tailed student *t*-tests were performed for all students who completed both pre- and post-RASI experience assessments, as well as the following combinations of concept map scores belonging to the following subpopulations: females, males, non-white minorities, and non-minority white (non-Hispanic) populations. Thus:

- Direct vs. RASI for all students ($n = 322$)
- Direct vs. RASI for all minority students ($n = 80$)
- Direct vs. RASI for all white students ($n = 242$)
- Direct vs. RASI for all female students ($n = 143$)
- Direct vs. RASI for all male students ($n = 121$)

Where datasets had different *n* sizes, two-sample student *t*-tests (*CI* of 95%) were performed:

- Direct non-minority vs. Direct minority
- Direct female vs. Direct male
- RASI non-minority vs. RASI minority
- RASI female vs. RASI male

The entire population and all subpopulation comparisons between *Direct* and *RASI* yielded statistically significant differences ($p < 0.001$). More importantly, *t*-test results revealed a statistically significant difference at the $p < 0.01$ level for minority vs. non-minority (white, non-Hispanic) student concept maps scores both pre- and post-RASI training. Further, *t*-test results revealed no clear differences between males and female performance on concept mapping after the direct instruction session ($p = 0.26$). However, after being taught weathering in the field through RASI, the difference revealed a statistical trend ($p = 0.067$).

Discussion of Quantitative Concept Map Analysis

Student understanding of weathering-related concepts deepened. In the field study participants indicated by an average concept map score increase of almost 14%. This score increase was further corroborated with open-ended questionnaire responses (below), but was more strikingly represented in pre- and post-RASI training concept map comparison. For example, the pre-RASI training concept map completed by student DN (Figures 1a and 1b) displays common misconceptions of weathering processes, while the post-RASI training concept reveals a greater grasp of concepts and a clearer connection to weathering form and processes, as evinced by the terminology and hierarchies. While crosslinks are absent from the post-RASI training map, the connections would have been made, ". . . if I'd only had 30 seconds more . . ." (quote from margin of DN's open-ended questionnaire).

Minority Student (non-white) and Female-Male Assessment

Among minority students in the K-12 classroom, science is often seen as boring and irrelevant (Basu & Barton, 2007). Unfortunately, this mantra continues into the undergraduate years (Clark, 1999; Oakes, 1990; Zuniga, Olson, & Winter, 2005). When minority students engage in a socially-relevant issue however (Tal & Morag, 2007), — especially with social support and a sense of autonomy to aid that issue — the learning potential increases (Basu & Barton, 2007). Rock art represents such an issue while also offering a sense of community (i.e., doing something for the greater good) and autonomy.

One clear finding of this study highlights the capacity of minority (non-white) students' ability to engage in the socially-relevant topic of rock art and their learning of science just as well as their non-minority (white, non-Hispanic) counterparts. Indeed, among minority students, the average

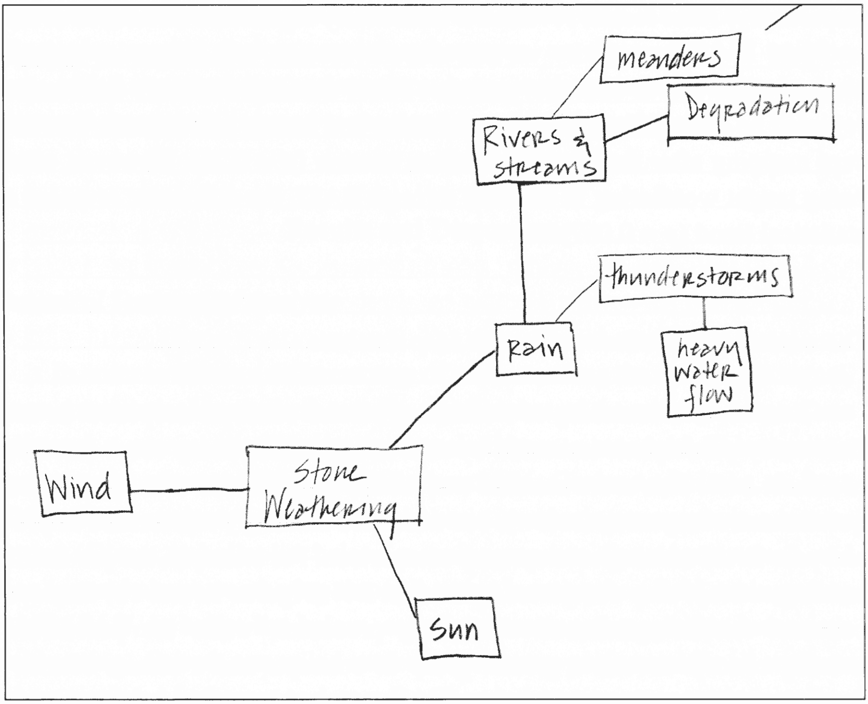

Figure 1a. Representative pre-RASI training concept map made by student DN displaying a very rudimentary understanding of weathering, even after having the topic via in-class lecture. According to the rubric, this concept map scored a total of 9/30: 5 points for correctly identifying the concept from a larger statement ("Stone Weathering"), 1 point x 2 valid examples (wind, rain), and 1 point x 2 for first-level hierarchies ("Stone Weathering" connecting to "Rain" and "Wind"). Compare to Figure 1b, where more appropriate weathering forms and processes are utilized.

concept map score increase approached 23%. The resultant minority concept maps also showed clear connections between weathering form and process. For example, student MM's pre-RASI training map displays one long crosslink to "rain" that "breaks down" "minerals" (Figure 2a) while the post-RASI training concept map displays a clearer connection between weathering forms and process (Figure 2b). Although there are no *verbal* crosslinks in MM's post-RASI training concept map, the form-to-process connection is explicit within the linear connections of concepts.

Further, although minority student pre-RASI training concept map scores were lower (16.2, $SD = 3.82$) than their white, non-Hispanic peers (17.2, *SD*

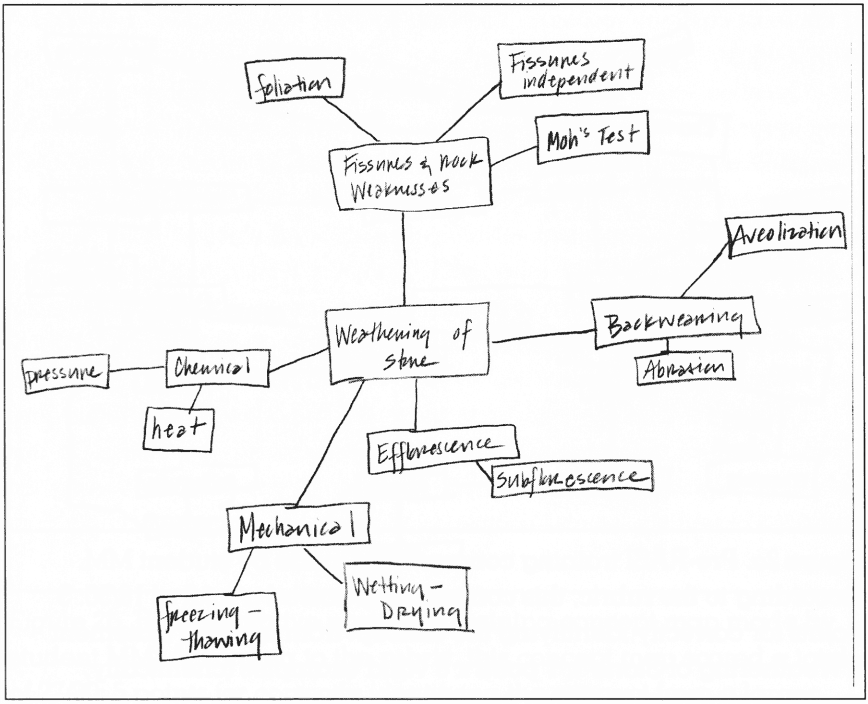

Figure 1b. Representative post-RASI training concept map made by student DN. According to the rubric, this concept map scored a total of 21/30: 5 points for correctly identifying the concept from a larger statement ("Weathering of Stone"), 1 point x 10 valid examples (fissures, foliation, Moh's test, aveolization [sic], Abrasion, Efflorescence, Subflorescence, mechanical, chemical, freezing-thaw, wetting-drying, fissures independent), 1 point x 3 for first-level hierarchies (("Weathering of Stone" connecting to "Chemical," "Mechanical," "Efflorescence," "Fissures & Rock Weaknesses," "Backwearing"), 1 point x 3 for second-level hierarchies (those stemming off the second-level hierarchies). Compare to Figure 1a, where very basic terminology is used to describe weathering forms and processes.

= 3.66), their post-RASI training concept map scores were higher: average non-minority scores increased from 17.2 to 20.4, and average minority scores increased from 16.2 to 23 ($p < 0.01$ minority vs. non-minority students). Perhaps unusual at first glance, the greater jump in learning by minority students, could be tied to RASI's ability of integrating culture preservation with science education, potentially increasing motivation in minority urban youth (Basu & Barton, 2007).

Female students also out-performed their male counterparts, as mea-

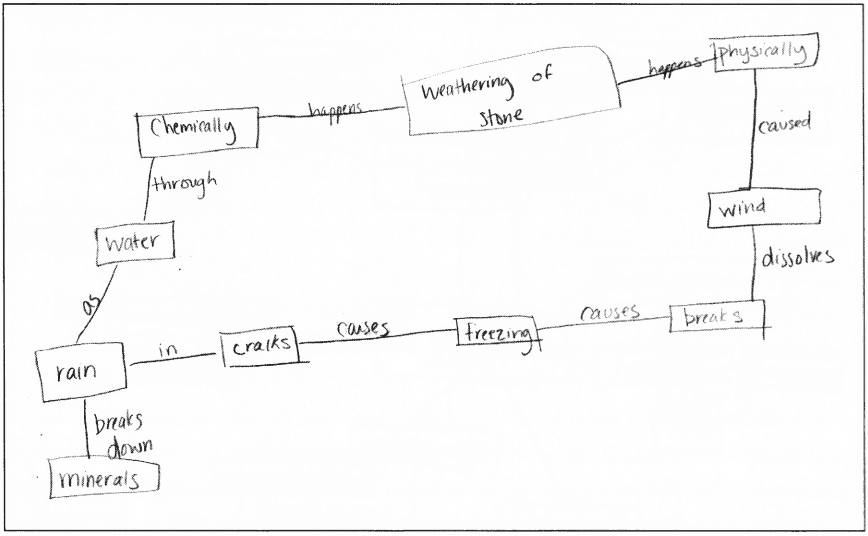

Figure 2a. Pre-RASI training concept map made by student MM. According to the rubric, this concept map scored a total of 18/30: 5 points for correctly identifying the concept from a larger statement ("Weathering of Stone"), 1 point x 8 valid examples (chemically, water, rain, cracks, freezing, breaks, wind, physically), 1 point x 2 for first-level hierarchies (physically and chemically connected to "Weathering of Stone"), 1 point x 2 for second-level hierarchies (connecting from "physically" and "chemically" to "rain"), 1 point x 1 third-level hierarchy ("minerals"). While this CM score may seem high, it in fact has very few weathering specific forms and processes. Compare with Figure 2b's complex usage and connections.

sured by concept map scores. Although female pre-RASI training scores were slightly lower than males (17.0 vs. 17.5), this difference was not statistically significant (p = 0.26). However, after learning weathering science through RASI in a field setting, females outperformed males by a difference of 5% (21.8 vs. 20.9, respectively, p = 0.067).

Pre and Post Open-ended Questionnaires

For the open-ended questionnaires, students were asked to answer four simple questions related to weathering form and processes. The questionnaire was designed so each question builds upon the previous until they are

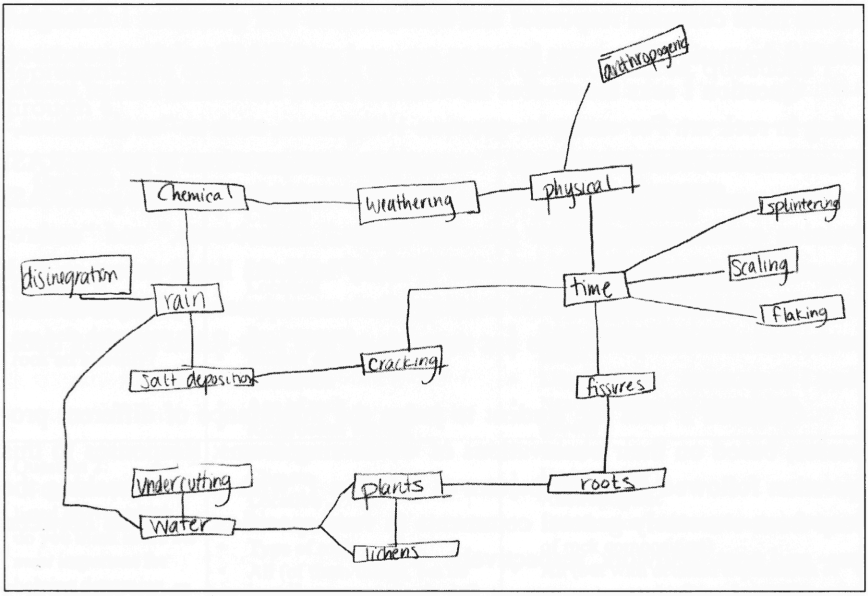

Figure 2b. Representative post-RASI training concept map made by student MM. According to the rubric, this concept map scored a total of 27/30: 5 points for correctly identifying the concept from a larger statement ("Weathering"), 1 point x 10 for valid examples (chemical, physical, anthropogenic, splintering, scaling, flaking, fissures, roots, plants, lichens, undercutting, salt deposition), 1 point x 2 for first-level hierarchies (physical, chemical), 1 point x 2 for second-level hierarchies (anthropogenic, rain), 1 point x 3 for third-level hierarchies (splintering-scaling-flaking, fissures-roots, rain-disintegration-salt deposition), 1 point x 5 for crosslinks (roots to plants, plants to lichens, water to plants, water to lichens, salt deposition to cracking). Note the dramatic change from Figure 2a in regards to weathering-specific terminology and connections.

asked, in question four, to integrate all their previous answers, coinciding with the concept mapping purpose to create the "...highest level of cognitive development. . ." where students ". . . can reason in terms of abstract entities and hypothetical situations" (Uzuntiryaki & Geban, 2005, p. 321). The fifth question asked students their opinion about rock art in general.

Overall, responses from pre-RASI training to post-RASI training changed significantly; students displayed a remarkable propensity for connecting weathering form and processes. Table 1 represents an amalgamation of the most common responses and demonstrates that questions 1 through 4 exhibit dramatic differences between pre- and post-RASI training responses.

Question 1 asks the student information about the overall role of weathering in rock art. For example, question 1 responses, such as "environment," "location," and "human damage," earned numerous mentions in the pre-RASI training comments, but those broad responses were replaced in the post-RASI training comments by "plant growth," "roots," "lithobionts," and "anthropogenic." Additionally, for question 1, many students listed desert or rock varnish as a factor in pre-RASI training when varnish usually helps stabilize rock; this misconception does not show up on *any* post-RASI training question 1 responses.

Question 2 asks the student to judge the importance of different processes, based on their observations of weathering forms. Responses to this question followed a similar pattern to question 1, with students making the leap from extremely general comments to very specific comments between pre- and post-fieldwork, respectively.

Question 3 extracts support for their generalizations. From question 3 responses, it is clear that, through the field-based experience with RASI, students connected weathering to more than simply rock "condition." Many of the post-RASI training responses to question 3 showed not only greater depth of weathering knowledge, but demonstrated specific connections between weathering form and processes. A few dozen students even suggested evidence could be shown by use of an index ("like RASI").

Question 4 requires higher order integrative thinking to assess how well students connect *specific* weathering forms to weathering processes. Pre-RASI training responses were, again, very general with very little explanation, and also included many dozens of "I don't know" (or similar) responses with no explanation. Conversely, while some post-RASI training responses to question 4 seem general, they actually demonstrate knowledge of how interactions between different weathering forms create weathering processes (e.g., one factor can lead to another). Accompanying the many specific responses were in-depth analyses of weathering form to process (e.g., fissures make it possible for plants to take root, and as roots grow they can break off pieces of the rock).

Question 5 tracked whether student perception of rock art management changed over the course of being trained in and using RASI in the field. While the pre-RASI training question 5 was limited to simple, trite responses after yes or no (with some students even leaving it blank), the post-RASI training responses were not only considerably more positive, but also accompanied by more explanatory responses. Where students gave a blank response on

Table 1

Representative comments from open-ended questionnaires, questions 1 through 4.

Question Asked	Representative PRE-field-based Comments	Representative POST-RASI training Comments
Question 1: What are factors that can help determine rock art stability?	• Climate • Weather (or weather factors, e.g., rain, wind, temperature) • Location • Type of rock • Environment • Human damage/ human interaction • Age of rock • Rock/desert varnish	• Fissures/fissuresols • Flaking/Scaling • Undercutting • Anthropogenic influences • Rock hardness • Rock composition/ type • Roots • Lithobionts • Nearby vegetation/ plants/plant growth
Question 2: Of the factors you listed above, which do you think is/are *the most* important for helping determine rock art stability?	• Weather • Climate • Location • Environment • Type of rock • All (of them/things, but no explanation) • Humans	• Fissures • Undercutting • Anthropogenic • Lithification (with explanatory note of rock composition) • All (but with detailed explanation of processes working in concert) • Plant growth/roots/ lithobionts
Question 3: What evidence could you give at a rock art site to show that the factors you listed above influence the stability of it?	• (Human) tampering/ disturbance of rock art • Look at other rocks around the site • The condition of the rock • The condition of the rock art • Recent erosion events • Age of rock • Past climate conditions	• Fissures (specifically) • Rock breaking apart because of one or more of the following: o Fissures o Undercutting o Anthropogenic factors o Flaking/Scaling o Roots in cracks o Plants • Undercutting (specifically) • Anthropogenic activities • An index (RASI)
Question 4: Do these factors *work together* to influence rock art stability? If so, how?	• Yes; General How's: o Climate o Human interaction o To provide evidence of rock stability • Don't know • Maybe/Possible/ Unsure	• Yes; General How's: o All factors work together o Everything affects the stability of everything else o One factor can lead to another • Yes; Specific How's: o Fissures lead to undercutting o Fissures lead to plants taking root which leads to rock breaking apart o The less desert varnish, the faster it will erode

the pre-training questionnaire and then gave a response on the post-training questionnaire, it was deemed a "change" in their perception of rock art. Yet, even more important, a strong majority of these changes reflect specific training of RASI, as evinced from specificity of weathering-related terminology on both the open-ended questionnaire (Table 1) and the concept maps. In all, nearly 72% of the participants ($n = 322$) changed their perception of rock art, of which almost 66% of the change in perception reflected field-based RASI training, as identified by specific RASI/weathering terminology used in their open-ended questionnaire responses.

Conclusion

The focus of this paper rests in understanding how to increase student engagement in a traditionally "dry" subject: weathering science (rock decay). Regardless of the discipline, students consistently confuse weathering with erosion (and vice-versa) and associate it with climate and weather, mainly because of the disciplinary definitional differences and misleading name (Dove, 1997; Hall, 2011). This paper moves beyond traditional pedagogic methods of note taking and memorizing terms and uses a socially-relevant issue (rock art) to engage students—especially minority (non-white) and female students—actively in weathering science.

In this study, using a scientific index (Rock Art Stability Index, RASI) and rock art (e.g., petroglyphs) as an interface, pre- and post-RASI training concept maps were collected and scored (after Hsu & Hsieh, 2005; West et al., 2002) with relevance to weathering form and weathering process. Concept maps have been used in biomedical fields for years to help students retain complex concepts (cf. All et al., 2003), and because weathering science exhibits similar complexities, concept maps were used in this study as a tool to understand student connections of weathering science terminology, static forms, and active processes. In all, 322 college-level introductory physical geography students experienced a hands-on, field-based pedagogy to understand weathering science. Assessment of concept map scores completed by students previous to and after receiving RASI training, revealed significant improvement in overall scores, but especially so in minority (non-white) students. While not all student concept map scores improved, as a check against the quantitative concept map analysis, an open-ended questionnaire was also administered to further corroborate data extracted from the concept maps.

Broadly speaking, as shown in this study, the significance of rock art management and its overlap with weathering science may help "hook" students, especially traditionally underrepresented students, into science. When introductory physical geography students learned an index of factors responsible for the stability of a priceless cultural resource, and applied that index in a real field setting, their learning exhibited a greater degree of understanding as revealed by concept map scoring. Further, because rock art is best studied in the field, students remain actively engaged through a hands-on field experience, learning first-hand in a learner-centered environment, the complex relationships often associated with science.

While focused specifically on rock art in this study, RASI can be modified for general assessment of stone decay on buildings, bridges, tombstones, or any other stone object, linking physical, biological, and cultural processes. Thus, as a method for engaging students in science, RASI produces an appropriate socio-cultural, learner-centered environment within a strongly scientific arena, allowing student autonomy and established social structures to remain intact — a trait especially important for minority students (Basu & Barton, 2007) — while still promoting active engagement in science.

References

All, A. C., Huycke, L. I., & Fisher, M. J. (2003). Instructional tools for nursing education: Concept maps. *Nursing Education Perspective, 24*, 311-317.

Allen, C. D., & Lukinbeal, C. (2011). Practicing physical geography: An actor-network view of physical geography exemplified by the Rock Art Stability Index. *Progress in Physical Geography, 35* (2), 227-248.

Basu, S. J., & Barton, A. C. (2007). Developing a sustained interest in science among urban minority youth. *Journal of Research in Science Teaching, 44* (3), 466-489.

Bauer, R. C., Birk, J. P., & Marks, P. S. (2007). *A conceptual introduction to chemistry*. Boston, NY: McGraw-Hill Higher Education.

Berg, L. R., & Hager, M. C. (2007). *Visualizing environmental science*. New Jersey: John Wiley & Sons.

Brady, N. C., & Weil, R. R. (2008). *The nature and property of soils* (14th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Brantley, S. L., & Chen, Y. (1995). Chemical weathering rates of pyroxenes and amphiboles. *Reviews in Mineralogy, 31*, 119-172.

Bullen, T., White, A., Blum, A., Harden, J., & Schulz, M. S. (1997). Chemical weathering of a soil chronosequence on granitoid alluvium. II. Mineralogic and isotopic constraints on the behavior of strontium. *Geochimica et Cosmochimica Acta, 61*, 291-306.

Burt, J. E., & Barber, G. M. (1996). *Elementary statistics for geographers* (2nd ed.). New York: Guilford Press.

Byers, S. J. (2008). *Introduction to forensic anthropology*. Boston, MA: Pearson Education.

Cerveny, N. (2005). *A weathering-based perspective on rock art conservation.* (Unpublished doctoral dissertation). Arizona State University, Tempe.

Cerveny, N. V., Dorn, R. I., Gordon, S. J., & Whitley, D. S. (2006). Welcome to RASI – Rock Art Stability Index. Retrieved from http://alliance.la.asu.edu/rockart/stabilityindex/RASI_Overview.html

Chakravarti, I. M., Laha, R. G., & Roy, J. (1967). *Handbook of methods of applied statistics* (Vol. 1). New York: John Wiley & Sons.

Christopherson, R. (2005). *Geosystems: An introduction to physical geography* (6th ed.). Upper Saddle River, NJ: Prentice Hall.

Clark, J. V. (1999). Minorities in science and math. *ERIC Digest Online, Report Number*, EDO-SE-99-02.

Daley, B. J., Shaw, C. R., Balistrieri, T., Glasenapp, K., & Piacentine, L. (1999). Concept maps: A strategy to teach and evaluate critical thinking. *Journal of Nursing Education, 38* (1), 42-47.

Dorn, R. I., Whitley, D. S., Cerveny, N. V., Gordon, S. J., Allen, C. D., & Gutbrod, E. (2008). The Rock Art Stability Index: A new strategy for maximizing the sustainability of rock art as a heritage resource. *Heritage Management, 1* (1), 37-70.

Dove, J. (1997). Student ideas about weathering and erosion. *International Journal of Science Education, 19* (8), 971-980.

Edwards, J., & Fraser, K. (1983). Concept maps as reflections of conceptual understanding. *Research in Science Education, 13*, 215-236.

Fardanesh, H. (2002). Learning theory approaches and teaching methods. *British Journal of Educational Technology, 33* (1), 95-98.

Fitzner, B. (2002). Damage diagnosis on stone monuments — in situ investigations and laboratory studies. Proceedings from the International Symposium of the Conservation of the Bangudae Petroglyph, May 7, 2002, Ulsan City, Korea (pp. 29-71). Seoul National University: Stone Conservation Laboratory.

Guastello, E. F., Beasley, T. M., & Sinatra, R. C. (2000). Concept mapping effects of science content comprehension of low-achieving inner-city seventh graders. *Remedial and Special Education, 21* (6), 356-365.

Hall, K. (2012). Special Session on Weathering at the Annual Meeting of the Association of American Geographers, February 24-28, New York.

Herrington, J., Oliver, R., & Reeves, T. C. (2009). Patterns of engagement in authentic online learning environments. *Australian Journal of Educational Technology, 19* (1), 59-71.

Hoffman, E., Trott, J., & Neely, K. P. (2002). Concept mapping: A tool to bridge the disciplinary divide. *American Journal of Obstetrics and Gynecology, 187* (3), S41-S43.

Hsu, L. L., & Hsieh, S. I. (2005). Concept maps as an assessment tool in a nursing course. *Journal of Professional Nursing, 21* (3), 141-149.

Jacobs-Lawson, J. M., & Hershey, D. A. (2002). Concept maps as an assessment tool in psychology courses. *Teaching of Psychology, 29* (1), 25-29.

Kinchin, I., & Hay, D. (2005). Using concept maps to optimize the composition of collaborative student groups: A pilot study. *Journal of Advanced Nursing, 51* (2), 182-187.

Kinchin, I. M. (2005). Reading scientific papers for understanding: Revisiting Watson and Crick (1953). *Journal of Biological Education, 39* (2), 73-75.

Kinchin, I. M., Hay, D. B., & Adams, A. (2000). How a qualitative approach to concept map analysis can be used to aid learning by illustrating patterns of conceptual development. *Educational Research, 42* (1), 43-57.

Lawless, C., Smee, P., & O'Shea, T. (1998). Using concept sorting and concept mapping in business and public administration, and in education: An overview. *Educational Research, 40* (2), 219-235.

Mayer, R. E. (2002). Rote versus meaningful learning. *Theory Into Practice, 41* (4), 226-232.

McCombs, B. L. (2002). *Assessment of learner-centered practices (ALCP) college survey validation results.* Denver, CO: University of Denver Research Institute.

McKnight, T. L., & Hess, D. (2007). *Physical geography: A landscape appreciation* (9th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Novak, J. D. (1990). Concept maps and vee diagrams: Two metacognitive tools for science and mathematics education. *Instructional Science, 19,* 29-52.

Novak, J. D., & Canas, A. J. (2008). *The theory underlying concept maps and how to construct and use them.* Pensacola, FL: Florida Institute for Human and Machine Cognition.

Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn.* New York: Cambridge University Press.

Oakes, J. (1990). *Multiplying inequalities: The effects of race, social class, and tracking on opportunities to learn mathematics and science.* Santa Monica, CA: Rand Corporation.

Pierce, J. W., & Kalkman, D. L. (2003). Applying learner-centered principles in teacher education. *Theory Into Practice, 42* (2), 127.

Plummer, C. C., McGeary, D., & Carlson, D. H. (2003). *Physical geology* (9th ed.). New York, NY: McGraw-Hill.

Pope, G. A., Meierding, T. C., & Paradise, T. R. (2002). Geomorphology's role in the study of weathering of cultural stone. *Geomorphology, 47*, 211-225.

Regan-Smith, M. G., Obenshain, S. S., Woodward, C., Richards, B., Zeitz, H. J., & Small, P. A. (1994). Rote learning in medical school. *Journal of the American Medical Association, 272*, 1380-1381.

Ruiz-Primo, M. A., & Shavelson, R. J. (1996). Problems and issues in the use of concept maps in science assessment. *Journal of Research in Science Teaching, 33* (6), 569-600.

Schunk, D. H. (2000). *Learning theories: An educational perspective*. Upper Saddle River, NJ: Prentice-Hall.

Stoddart, T., Abrams, R., Gasper, E., & Canaday, D. (2000). Concept maps as assessment in science inquiry learning — a report of methodology. *International Journal of Science Education, 22* (12), 1221-1246.

Suarez, D. L., & Wood, J. D. (1996). Short- and long-term weathering rates of a feldspar fraction isolated from an arid zone soil. *Chemical Geology, 132*, 143-150.

Tal, T., & Morag, O. (2007). School visits to natural history museums: Teaching or enriching? *Journal of Research in Science Teaching, 44* (5), 747-769.

Uzuntiryaki, E., & Geban, O. (2005). Effect of conceptual change approach accompanied with concept mapping on understanding of solution concepts. *Instructional Science, 33*, 311-339.

Van Zele, E., Lenaerts, J., & Wieme, W. (2004). Improving the usefulness of concept maps as a research tool for science education. *International Journal of Science Education, 26* (9), 1043-1064.

Viles, H. A., Camuffo, D., Fitz, S., Fitzner, B., Lindqvist, O., Livingston, R. A., et al. (1997). Group report: What is the state of our knowledge of the mechanisms of deterioration and how good are our estimations of rates of deterioration? In R. Snethlage (Ed.), *Report of the Dahlem Workshop on "Saving Our Architectural Heritage: The conservation of historic stone structures," Berlin, March 3-8, 1996* (pp. 95-112). London: John Wiley & Sons.

Walczyk, J. J., Ramsey, L. L., & Zha, P. (2007). Obstacles to instructional innovation according to college science and mathematics faculty. *Journal of Research in Science Teaching, 44* (1), 85-106.

West, D. C., Park, J. K., Pomeroy, J. R., & Sandoval, J. (2002). Concept mapping assessment in medical education: A comparison of two scoring systems. *Medical Education, 36* (9), 820-826.

Whitley, D. S. (2001). *Handbook of rock art research.* Oxford: Altamira Press.

Whitley, D. S. (2005). *Introduction to rock art research.* Walnut Creek: Left Coast Press.

Wright, R. T. (2008). *Environmental science* (10th ed.). Upper Saddle River, NJ: Pearson Prentice Hall.

Zuniga, K., Olson, J. K., & Winter, M. (2005). Science education for rural Latino/a students: Course placement and success in science. *Journal of Research in Science Teaching, 42* (4), 376-402.

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