Ecological restoration monitoring: A citizen science initiative

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Abstract

The Rocky Mountain Field Institute is a leading non-profit organization in southern Colorado that performs extensive restoration efforts in public lands in the Southern Rocky Mountain region. The current restoration efforts are based on best practices in the industry, but they are not validated by field monitoring. Therefore, this proposal introduces a novel citizen science initiative in ecological monitoring and describes how video instruction may well facilitate the training of citizen scientists. A literature review develops the context and efficacy of video instruction. A detailed analysis of the situation and a description of the training process follows. The appendices outline the learning outcomes and monitoring protocols that direct the training initiative.

Ecological restoration monitoring: A citizen science initiative

Citizen volunteers are engaged in several facets of public lands maintenance and conservation. They engage in hands on restoration activities and collect the ecological data necessary to maintain healthy, functioning ecosystems. Their volunteer participation is required because federal and philanthropic funds to support this work are decreasing (Gollan, De Bryun, Reid, & Wilkie, 2012). Simultaneously, the overall need for ecological restoration and monitoring of public lands is increasing due to anthropogenic environmental change and increased recreational use (Hobbs & Norton, 1996). This proposal describes how video instruction has the potential to educate volunteers to promote their understanding of the restoration context and to enact monitoring protocols with expertise. The Rocky Mountain Field Institute (RMFI) is the pilot organization with whom this solution may be implemented and therefore organizational and geographic specifics discussed are relevant to this organization.

The Rocky Mountain Field Institute is a non-profit organization that “promotes the conservation and stewardship of public lands in the Southern Rocky Mountain region through volunteer-based trail and restoration projects, environmental education, and restoration research” ("RMFI," 2016). The organization is managed by a small team of employees that plans projects, seeks funding, negotiates organizational partnerships, manages volunteers who conduct the field work, and records volunteer impacts. RMFI’s current educational programming includes an annual staff training, an annual volunteer training, and a summer field semester for college students called Earthcorps.

RMFI’s training efforts are temporally incongruent with the field work enacted by volunteers because training occurs in the spring before the field season commences. Video-based instruction has the capacity to facilitate knowledge attainment at any time during the field season because digital training modules are asynchronous and can be accessed numerous times, making them an exceptional tool for learning. Superior training modalities will not only lead to volunteers' knowledge attainment and satisfaction, they will result in superior data collection, which will in turn promote the validity and reliability of volunteer data collection and ecological restoration implementation. This proposal addresses a novel citizen science program and training initiative, but the inherent research about video instruction is potentially useful for existing programs as well.

Review of literature

The quality of volunteer data collection is a topic of much debate due to their lack of scientific training and credentials (Crall et al., 2011; Gollan et al., 2012). To address issues of data collection quality, this proposed solution uses asynchronous, instructional videos to train volunteers in citizen science initiatives. Instructional videos and other digital learning media play an increasing role in other educational contexts, and therefore it is reasonable to assume that video instruction can have positive learning effects in the realm of citizen science.

Instructional videos are used in a number of educational contexts and their use has been investigated with quantitative and qualitative analysis. Mathematics education has seen a productive shift from didactic instruction to student-centered, dialogic, constructivist approaches (Abdulwahed, Jaworski, & Crawford, 2012) and computer-assisted instruction (Ornstein, Pajak, & Ornstein, 2015). Abdulwahed, Jaworski, & Crawford (2012) used a number of key words to compose a literature review that explores facets of constructivism in mathematics education. They found that multimedia tools including lecture videos facilitate student-centered approaches to autonomous learning. Computer-assisted instruction provides advantages for diverse students because it is adaptive, patient, and nonjudgmental (Ornstein, Pajak, & Ornstein, 2015). When concurrent, independent cohorts of students took either instructor-led courses or online courses that were 100% mediated by computer activities, students who took online sections achieved higher scores and expended less effort (in hours) than in-class students (Potocka, 2010). This study design relied on principles of mastery learning, in which students must demonstrate competency before gaining access to the final examination. Only one online student was unsuccessful in the final exam efforts compared to 12%, 3%, and 15% of students in the classroom sections. This is a strong testament to the importance of gated, programmed instruction.

Research from other fields indicates that participants gained knowledge in asynchronous online training that addressed procedural knowledge (Gagnon et al., 2015; Serna et al., 2016). Instructional video training for pediatric health care professionals increased their knowledge and procedural performance (Cheng, Lang, Starr, Pusic, & Cook, 2014). Technology-assisted instruction is a major component of the rising discipline of online higher education theory and practice (Stravredes, 2011). In the realm of citizen science, video-based training for volunteers was an effective instructional strategy for invasive species identification (Starr et al., 2014). Technology-centered collaboration projects facilitate communication and knowledge transfer among scientists, land managers, and citizen scientists (Gray, Mellor, Jordan, Crall, & Newman, 2014). Participants in online learning report that they are more ready to engage in self-directed learning after an online training experience (Gagnon et al., 2015). Students for whom attending school is not their primary daily task benefit from video asynchronous instruction because it allows for more flexible learning (New Media Consortium [NMC], 2015). These studies indicate that instructional videos, by way of their intentional, repetitive modeling of procedural learning, are effective learning tools.

As evidenced by the above narrative, video instruction is an effective learning tool in many educational contexts. It is also a nuanced tool that, in practice, employs a number of instructional strategies. Some instructional videos are didactic in nature. For example, the MOOC revolution is a broad trend in which lecture-based instruction from leading institutions of higher education is shared openly through online platforms like YouTube (Vargas, 2014). This teacher-centered approach expands the availability of learning opportunities for the masses, but it does not result in evidence-based proof of effectiveness since participation in MOOCs is voluntary and involves no assessment. Lecture-videos lack the student engagement component that brings students into an active learning context (Vargas, 2014). When validated through student assessment, results indicate that passive participation in lecture videos does not result in the desired student achievement (Abdulwahed et al., 2012).

In contrast, instructional media that incorporates principles of programmed instruction results in greater student achievement (Potocka, 2010). In programmed instruction, the learning outcomes are presented in a logical sequence with controlled release of the information. The controlled release of the information is responsive to student performance, which is required directly proceeding the programmed instruction. These *shaping principles* (Skinner, 1954) create a more active learning experience. They also facilitate more individualized instruction because students move through the programmed learning units at their own pace, according to their command of the subunits of the learning outcomes.

Mastery instruction is related to programmed instruction and can guide the effective use of video instruction (Ornstein et al., 2015). Mastery instruction is a branched pattern of instruction that requires students to validate their knowledge through formative assessment. When students struggle with a specific learning outcome, they are afforded additional instruction until mastery is demonstrated. Research shows that mastery instruction closes the performance gap and results in higher average achievement among cohorts of students (Potocka, 2010).

Students are often described according to their dominant learning mode. For example, students can be described as visual, aural, read/write or kinetic learners following the VARK learning styles inventory (Fleming & Baume, 2006). While the evidence for multiple learning styles is ambiguous at best (Martinez, 2010), some research indicates that multimodal stimuli is beneficial to the learning process (Gillow-Wiles & Niess, 2013). Videos are considered multimodal tools that have audio, written words, and imagery provide stimuli for all kinds of learners (Kress & Selander, 2012).

Regarding student preference for different video styles, students prefer screencast recordings to recorded lecture videos (Guo et al., 2014; Sadik, 2015). Dynamic tablet drawing tutorials are more engaging than slide presentations that are static when presented in the video (Guo et al., 2014). Instructional videos that include the instructor's face lead to greater student engagement (Guo, Kim, & Rubin, 2014) although videos in which the face is periodically shown pose cognitive load issues (Kizilcec, Bailenson, & Gomez, 2015). The length of the instructional video is also an important design consideration. Research indicates that after 15 minutes in lecture, student attention declines (Johnstone & Percival, 1976). Likewise, research indicates that the optimal length of an instructional video is six minutes (Guo, 2013).

This literature review indicates that video instruction is a valid approach to facilitate learning in numerous contexts and for students with diverse learning preferences and temporal availability. Therefore, video instruction may well facilitate asynchronous, self-directed learning for citizen scientists. The findings of these studies inform the theoretical underpinnings, production style, and duration of the proposed instructional training videos.

Analysis of the Situation

Nature-based recreation has increased steadily since the advent of the public lands management system in the mid-20th century (Balmford et al., 2009). In the last few decades, the use of American public lands near urban interfaces has increased dramatically as an increasing number of Americans live in urban areas ("US Census," 2012). The site of RMFI's citizen science initiative is the Garden of the Gods Park (herein referred to as the Garden) in Colorado Springs, CO. The Garden is the busiest city park in the nation, with 2 million visitors each year (Tatro, 2015). The park is located on the west side of Colorado Springs, a city of 445,000 people ("Quickfacts," 2014). The park is 1,367 acres and at the center are iconic geologic features that attract local, national, and international visitors (Parks, Recreation, and Cultural Services, 2014). A variety of non-motorized recreational uses are permitted on trails in the park including hiking, road and mountain biking, rock climbing, and horseback riding.

The park is open 365 days of the year and the weather permits near constant use. In addition to the intense use, the geology of the area contributes to the highly erodible mineral soil. This soil underlies a very fine to nonexistent layer of organic material resulting from the slow-growing, drought tolerant vegetation. While the Garden does have a maintenance crew, the work of maintaining non-motorized trails largely falls to non-profit organizations and their volunteers. This partnership between the Garden and non-profit organizations called the *Garden of the Gods Community Restoration Program* commenced in 2002 after a two-year study described the deteriorating ecological condition of the Garden (Byers, Ebersole, & Hesse, 2000). RMFI leads dozens of volunteer work days in the Garden from March to November. In 2015, 1,299 RMFI volunteers contributed 6,464 hours of service on 58 work days, a total work value of $149,200 according the U.S. Bureau of Labor Statistics estimate of the value of volunteer time ($23.07/hr) (Tatro, 2015).

RMFI volunteers in the Garden complete a variety of restoration-related tasks including trail maintenance, social trail closure, and revegetation. Aside from anecdotal monitoring of this work conducted by Garden rangers and RMFI staff, there is no restoration monitoring protocol currently in place. Without active monitoring, there is little scientific justification for the techniques used to reduce erosion and human impact on the landscape. A restoration monitoring program would provide the numeric and longitudinal data necessary to validate the trail maintenance techniques used in the Garden. These data would provide evidence to either support the current restoration practices, or compel novel approaches for increased restoration impact. A novel citizen science program would engage volunteers in a rich monitoring experience that has the potential to contribute broadly to restoration initiatives beyond the Garden. Citizen science has been shown to both increase data collection capabilities in a number of scientific concepts (Tulloch, Possingham, Joseph, Szabo, & Martin, 2013) and increase community investment and stewardship in public lands and species protection through collaborative, stakeholder involvement (Watkins, Massey, Brooks, Ross, & Zellner, 2013).

This citizen science project will measure the physical change in recreation trails before and after maintenance is conducted in the Garden. Three objectives are identified for this project. The first objective is to engage volunteers in citizen science. The second objective is to train these volunteers so they can both understand the ecology of the Garden and the data collection protocols necessary to advance the monitoring effort. The third objective is to enact a high quality monitoring protocol in the Garden that contributes to restoration efforts locally and beyond, and that contributes to the body of peer-reviewed ecological restoration literature.

Solution Supported

Instructional Video Design

The solution proposed is a series of instructional training videos to support the education of volunteer citizen scientists who are interested in collecting data to monitor restoration efforts in the Garden. Each instructional video is more than six minutes in length. Each presents multimodal information including field images and videos, written words and audio explanation. The videos do not include an instructor image since the videos facilitate autonomous learning. The videos describe the ecological framework for the restoration initiative. This focus deepens the volunteers' understanding of the context in which they will carry out monitoring procedures. Volunteers' foundational knowledge will radiate to other trail users through their interactions in the field and in other social contexts.

Conceptual and procedural knowledge are two knowledge dimensions described by Anderson and Krathwohl (2001). Table 1 presents the learning objectives for each video.

Table 1

Learning Objectives for Citizen Scientists

By the end of the training video sequence, volunteers will be able to:
Explain how recreational impacts affect trails and their environs
Describe the effects of erosion and identify erosion in landscape photos
Identify flora and fauna present
Define slope and aspect and know how to measure it
Take tread depth and width measurements in the field and record them in the datasheet

Data from 2015 indicates that current RMFI volunteers have a broad age classification as shown in Figure 1. The disproportionate number of participants under the age of 18 relates to the abundance of whole-class educational service field trips RMFI hosts in the fall after the school year begins. While it is possible that youth participants will practice the citizen science monitoring protocols as an educational experience, it is unlikely that they will carry out the on-going program. Therefore, the videos are designed with the adult learner in mind and principles of andragogy are applied. Knowles' principles of andragogy (Knowles, Holton, & Swanson, 2011) characterize the adult learner as one who needs to know why the learning experience is necessary and of immediate value. Adults need experiential learning that involves problem-solving. This training project's focus on conceptual knowledge and its real-world application to ecological stewardship as a personal ethic are aligned with these andragogic principles.

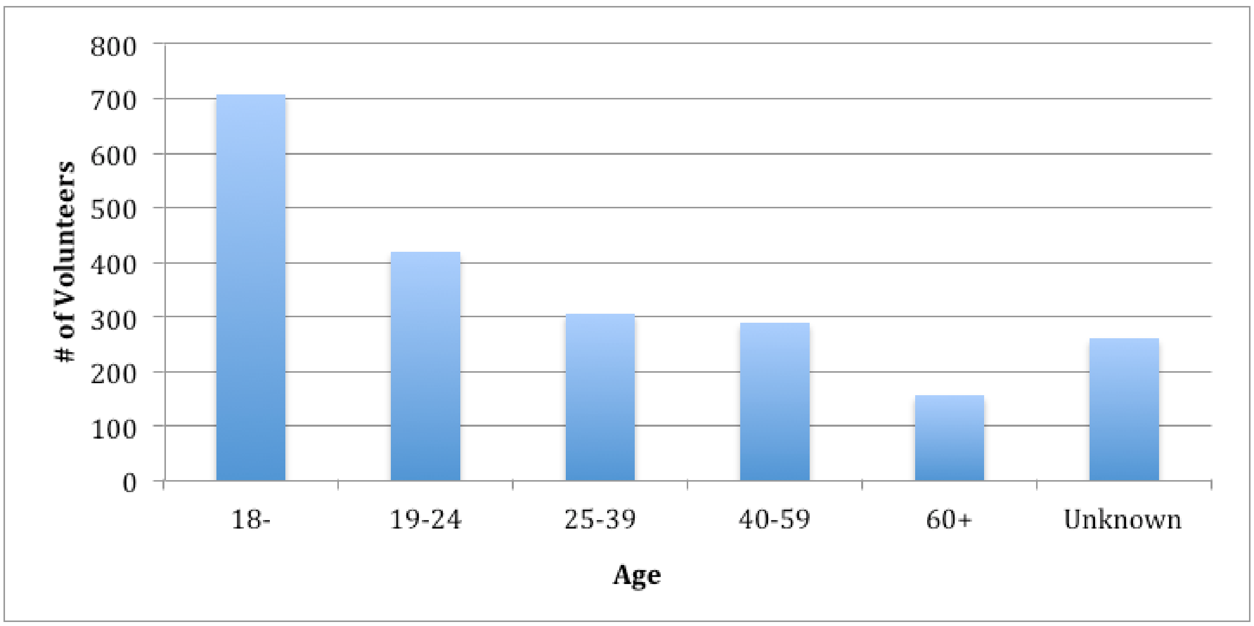

Figure 1. 2015 RMFI volunteer participation data

Assessment of Learning Outcomes

The training process is designed following principles of programmed instruction. Before engaging in the video instruction modules, volunteers take a pre-test to measure their prior knowledge entering the learning experience. They then take an analogous post-test to measure the knowledge gained during the learning experience. Volunteers can take the test repeatedly, but not more than once per day. The post-test results indicate to the test-takers what questions they got wrong, but it will not reveal the answers to these questions. They can watch the videos again and read the supporting documents to find the answers. These digital assessments serve as an entry requirement for field work. Volunteers cannot engage in the field validation event until they have passed the post-test. After passing the post-test, volunteers engage in a face-to-face, field-based training experience with a mentor. A field experience is typically the first engagement of training for citizen scientists, therefore the video training sequence presents an improvement in training pedagogy and is likely to result in more accurate and reliable data collection by volunteers.

The goal of the video-based training is to have volunteers enter the field with a robust and confirmed understanding of the field task and its conceptual foundations. This preparatory, video-based learning is likely to maximize the experiential learning by creating *a priori* knowledge that can be recalled in the field. The opportunity for repetitive training engagement with instructional videos facilitates mastery. In a traditional context where a training initiative cannot be repeated until the next training event, which might be not be available until a subsequent field season, volunteers who do not learn the required concepts and tasks are prevented from participating. Alternatively, they may participate anyway, but the data they collect might be compromised by this failure to learn. If this training initiative results in improved data collection, it will provide a model for more successful citizen science initiatives and potentially quell the on-going debate about the quality of citizen science data collection.

Assessment of Project Objectives

As previously stated, the first project objective is to engage volunteers in citizen science. The second objective is to train these volunteers so they can both understand the ecology of the Garden and the data collection protocols necessary to advance the monitoring effort. The third objective is to enact a high quality monitoring protocol in the Garden that contributes to restoration efforts locally and beyond, and to the body of peer-reviewed ecological restoration literature. The first objective will be met when volunteers become interested in participating in the program. The work of soliciting participation will largely fall on the shoulders of Rocky Mountain Field Institute staff. Therefore, a strong relationship between the organization, the Garden of the Gods park, and the researcher needs to be cultivated during the planning phases of this project. Ultimately, the organization will be the entity to decide if the citizen science initiative will be implemented. Due to the nature of this dissertation-related work and requirements for IRB approval, successful implementation of this initiative will occur in summer 2017.

The assessment of the second objective is the purview of researchers who will analyze the learning outcomes of the citizen scientists in both quantitative and qualitative measures. The pre-posttest design of the student assessment will provide evidence as to the effectiveness of the instructional videos. Qualitative analysis will include field mentor interviews in which the efficacy of the pre-field training will be interpreted in the field as preparedness for the field mentoring experience. Qualitative analysis will also involve participant interviews in which participant perceptions are assessed. Their satisfaction with and perceptions of the training's effective will be the focus of these evaluative inquiries.

The assessment of the third objective is the purview of land managers, resource consultants, and eventually the consumers of peer-review literature that may well result from these citizen science initiatives. Ultimately, restoration managers including RMFI and Garden staff will determine whether or not the monitoring efforts provides valuable information for restoration practice, which is the ultimate, practical goal of this monitoring effort. If peer reviewers deem the scientific process to be robust, valid, and reliable, publication will result.

Conclusion

In this proposal, the concept of video instruction is discussed in the context of citizen scientist training. Peer-reviewed and scholarly literature provide a rich foundation for the development of this project. Drawing upon educational theory, citizen science phenomena, and ecological restoration practice, the Garden of the Gods citizen science initiative has the potential to have impacts on the land, on the people and organisms that use and benefit from the land, and on the greater scientific community. A rising trend in ecology is the importance of the human dimension. This proposal is an example of how land management and ecological preservation can be facilitated by wise attention to human dimensions. The interdisciplinary approach transcends disciplinary silos and has the potential to inform the scientific community of educational theory and to strengthen the practice of citizen science at large.

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Appendix A

Restoration Questions and Objectives, Data Collection Objectives, and Monitoring Information

Restoration Questions

How does the trail change over time?

How do slope and aspect relate to trail tread depth and width?

Do structures slow the rate of change on a trail? Is this correlated with slope and aspect?

Research Objectives

Create a long-term monitoring data set that records trail depth and width over time.

Analyze the effect of slope and aspect on trail dynamics over time.

Compare depth and width before and after structures are implemented.

Data Collection Objectives

Measure the trail tread depth and width over time

Measure the slope and aspect of trail (once/trail)

Collect photo point data over time

Monitoring Information

Schedule: once per month and after storm events

Location: Garden of the Gods

Equipment needed: camera, map of photo points, trail map, 1 meter tape, 1 meter stick, compass with slope meter

Field notebook includes: Diagram of measurements, brief explanation for measurement of aspect and slope, data collection sheet, photo point diagram