Incorporating Informal Learning Environments and Local Fossil Specimens in Earth Science Classrooms: A Recipe for Success

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Abstract

In an online graduate paleontology course taken by practicing Earth Science teachers, we designed an investigation using teachers' local informal educational environments. Teachers (*N* = 28) were responsible for photographing, describing, and integrating fossil specimens from two informal sites into a paleoenvironmental analysis of the landscape in which the fossils were originally deposited. Our practicing teachers also developed mini-units for their individual classrooms, utilizing the fossils and the informal sites they investigated. Not only did teachers develop a multitude of innovative and effective activities, but they were overwhelmingly enthusiastic about incorporating aspects of local informal sites within their individual classrooms. Content analysis of teachers' anonymous responses revealed three stable findings: 1) The informal sites and local fossils affirmed the importance of the local environment and put it into a larger context, 2) directed student activities within informal sites can maximize learning, and 3) informal sites provide a context for information and can supply an interdisciplinary "big picture" for students. We propose that directed interdisciplinary investigations that incorporate the local environment may enhance science learning at informal education sites.

As students, most of us thoroughly enjoyed the opportunity to step outside the classroom for a day filled with new places to visit, fun-filled activities, and the obligatory bus ride. After all, this was essentially a day "without school." As science teachers, however, some of us may have hesitated to bring our classrooms to a museum, arboretum, botanical garden, or fossil park. Although a chance to escape the traditional classroom was a positive factor, could students really learn in these informal environments, or did they feel inundated with a multitude of exhibits, often precisely labelled and "caged" within glass displays or behind fenced areas?

Similar to traditional classrooms, the quality of informal education can vary across a broad spectrum, with some instructional methods being more effective than others. "One size" in instruction does not necessarily "fit all." Our students' backgrounds are often quite varied, yet important, when planning science lessons. Fortunately, our previous research with the Geological Sense of Place writing template revealed that the local landscape had a strong influence on the majority of our students (Clary & Wandersee, 2006). Students typically indicated that local rock types, landforms, and experiences had the greatest impact in their youth, as opposed to events and products that were highly publicized in textbooks and television documentaries. Therefore, in our Earth Science classrooms, we hypothesized that an integration of fossils within local informal environments, such as museums, national parks, and nature centers, might enhance informal learning opportunities.

Active Learning, Informal Learning Environments, and Local Fossils

Science education research has affirmed that student-centered and active learning strategies can result in learning benefits for our students (Lawrenz, Huffman, & Appeldoorn, 2005; McConnell, Steer, & Owens, 2003; Michael & Modell, 2003). One benefit of active learning techniques is improved student understanding of the research process (Felzien & Cooper, 2005; Hemler &

Repine, 2006). Both increased learning and positive student attitudes have been reported for inquiry-based biology exercises (Lord & Orkwiszewski, 2006), while higher grades have been correlated with informal, active-learning investigations with fossils (Clary & Wandersee, 2008). Burr, Chiment, Allmon, and Rigby (2003) have also reported success in using an unidentified fossil to engage students, as well as the public.

The value of informal education and free-choice learning is well-established (McComas, 1996, 2006; Wandersee & Clary, 2006). In addition to being the default learning environment for the majority of the adult population, students engage in this type of learning more often than learning in traditional school environments (Falk & Dierking, 2002). As a result of the value of informal education, researchers have investigated the theoretical bases, motivators, and assessments of learning in informal settings (Anderson, Lucas, & Ginns, 2003; Falk, 2001; Falk & Dierking, 2000; Meredith, Fortner, & Mullins, 1997; Orion & Hofstein, 1994; Rennie & Johnson, 2004). Informal educational programs have also been shown to engage citizens in global problems, independent research, and data collection (Roy & Doss, 2007).

Informal educational settings also can offer rich learning opportunities for our students (Anderson, Lucas, & Ginns, 2003). Field experiences provide environmental context and land ethic (McLaughlin, 2005). Furthermore, field experiences can reach students who have difficulties grasping subject matter, and provide holistic experiences that are retained (Bernstein, 2004). Elkins and Elkins (2007) indicated that significant geological concept gains could be achieved in a field-based course. Therefore, science educational research suggests that learning benefits can accrue in Earth Science classrooms with active learning strategies and informal environments. However, it should be noted that although active learning and informal environments may facilitate meaningful learning, results in each classroom will vary and are dependent upon the quality of instruction.

Methods

The graduate course, History of Life, is taught entirely online through a distance learning program at a research university in the southern United States (US). This course is part of the Teachers in Geosciences Program (TIG), in which practicing teachers earn a non-thesis master’s degree through courses taught entirely in an online environment. The exception to the online course work is a 2-week field application capstone course. The majority of students enrolled in the History of Life course are practicing Earth Science educators enrolled from primarily across the US (n = 16 in 2007 and n = 12 in 2008). Therefore, we use the terms “practicing teachers” and “students” synonymously in our descriptions and discussions. These practicing teachers are either in their second year of the TIG program, or have completed their master’s degree and are enrolled in a “Master’s Plus 30” online program. The majority of these teachers are employed within US public schools, teaching science at the middle (US Grades 6-8) and high school levels (US Grades 9-12).

The History of Life course is taught each spring semester. The course is divided into 12 weekly units; three units combine to form one quarter. During each quarter, our students are assigned laboratory exercises with accompanying application classroom activities. Application activities typically involve in-depth research of a particular topic, and the subsequent development of lesson plans, with materials and assessments, that the practicing teachers can directly incorporate into their own classrooms. Therefore, application activities involve the implementation, at an appropriate level for the teachers’ individual classrooms, of the content researched in the History of Life course. Quarterly assignment topics are complementary to the course content presented through video lectures, reading assignments, and online discussion board conversations. Course content includes the fossil record, systematics, evolution, functional morphology, paleoecology, biostratigraphy, biogeography, and paleobotany. The greatest emphasis is on invertebrate phyla, although protists, plants, and vertebrates are discussed.

In 2006, we designed an active-learning assignment in which each practicing teacher autonomously planned and investigated fossil outcrops in his/her geographic area. Our students were responsible for photographing, identifying, and discussing fossil specimens that they procured in their local field areas (Clary & Wandersee, 2008). Anonymous feedback revealed that practicing teachers consolidated the information presented in the History of Life course through this active, informal assignment.

Some teachers encountered difficulties with local fossil procurement, primarily because of weather constraints and physical access to sites. Therefore, in 2007, we required our students (n = 16) to investigate fossils and paleoenvironments through established informal education sites, including national parks, university museums, and nature centers. Fossil specimens at these locations could be displayed in cases, in situ at the site, or housed in an organization's collections. All specimens, however, had to be accessible by the general public. Our practicing teachers selected a minimum of two informal education sites within traveling range, and photographed a minimum of 18 specimens, with each being a different species. A total of five phyla and/or divisions were required to ensure adequate depth and breadth of the paleontology content covered in the course. Informal sites were unique among students, and each site could be utilized by only one practicing teacher during the semester. Specific guidelines were provided for fossil photography, including the incorporation of a colored pencil and a unique university logo for scale. Objects used for photographic scales were changed each semester. This ensured that students visited the site during the assignment, and did not retrieve photographs from earlier excursions or former students.

After practicing teachers located their specimens, they had to describe the distinguishing features and explain the reasons behind the classification. For example, trilobites had to be identified through discussion of the cephalon, thorax, and pygidium characteristics. Geographic ranges and geologic ages were required. Often, this information was posted with displayed fossils; otherwise, our practicing teachers retrieved this from interpretation of the local stratigraphy and/or textbooks. They then integrated the specimens into a discussion of three depositional paleoenvironments represented by their fossil selections. This mandated a reconstruction of the conditions and locations under which the fossilized organisms once lived.

Our directions for Part II of the informal learning assignment required the practicing teachers to develop a mini-unit for their own middle or secondary science classrooms that used the fossils they had photographed and the paleoenvironments they had identified. A description of each practicing teacher's current classroom (grade level, number of students) was mandatory, along with the identification of any of their students with special needs (and subsequent modifications of the activity and/or assessment, if necessary). This ensured that all learners in each teacher's individual classroom were addressed. Learning objectives, state curriculum benchmarks or grade level expectations, and the US National Standards that the fossil activity addressed were to be included. Our teacher-developed activities needed to incorporate a minimum of two learning styles, and address higher-order thinking skills, such as application, analysis, synthesis, and evaluation. Finally, our practicing teachers had to develop an assessment tool for their activity, appropriate for their learners and their individual classroom.

A rubric for scoring the completed projects was posted on our course website. Our detailed rubric included a checklist for each fossil specimen (proper photograph, identification, distinguishing features, collection site, geologic age, range) and the mini-unit (classroom description, objective, national standards, state benchmarks, higher order activities, specification of learning styles, appropriate assessment tool). Students submitted their completed projects electronically through the course website, and the instructor's individual scores and comments were posted to students via their quiz link for the application activity. At the end of each semester, an anonymous electronic survey was posted for our practicing teachers. Open-ended questions sought the practicing teachers' opinions on the History of Life informal educational activity.

The success of this assignment in 2007 prompted us to repeat it in 2008 (n = 12). Students were again assigned a paleoenvironmental analysis using the fossils photographed from a minimum of two informal sites. The logo used for scale in the fossil photographs was changed to a modified logo of the university mascot. Our students were again assigned mini-unit development for their individual classrooms.

Analysis and Results

Informal sites and fossil choices. All students in the 2008 class researched informal sites, including museums, state parks, public lands, and fossil parks, within the continental US (Figure 1). Enrollment in the TIG program, and subsequently in the History of Life course, is influenced by the US states that have implemented an Earth Science course option or requirement at the high school level. In 2007, our practicing teachers had greater geographic dispersion, and the informal sites of the 2007 class also included Mexico and the Caribbean. Between the 2 years, some informal sites were selected more frequently, and were included in informal investigations in both 2007 and 2008 (Table 1). Although some students encountered initial difficulties in selecting informal sites, all students managed to locate the required minimum number for the assignment. Several well known US museums and informal sites were researched by students, including the Smithsonian, the Harvard Museum of Natural History, and the Page Museum at La Brea. However, students residing in areas without famous informal sites managed to incorporate smaller, local museums and nature parks (Figure 2).

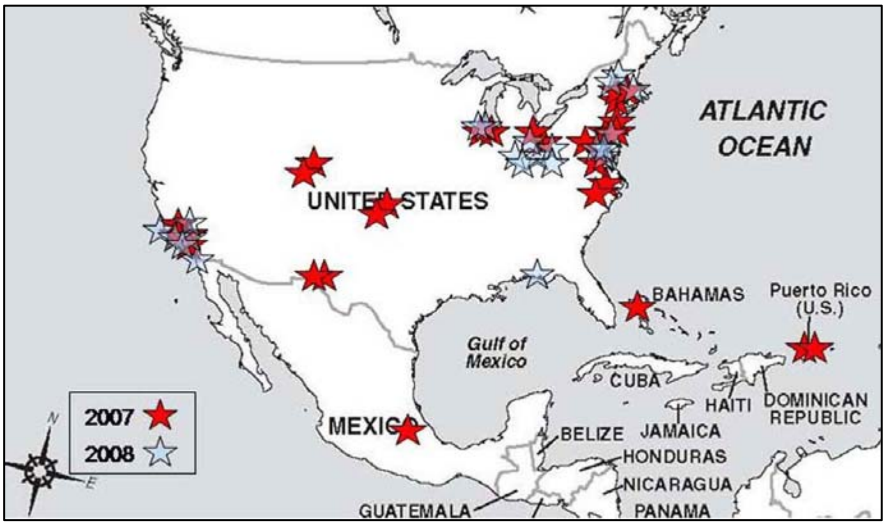

Figure 1. The geographic distribution of informal learning sites chosen by students in 2007 and 2008. Many students from the eastern US and southern California are enrolled in the online master's program, leading to greater density of informal sites from these areas.

Table 1
The Informal Site Selections of Practicing Teachers

Location	Site
United States	
California	**La Brea--Page Museum** *Laguna Hills Community Center* **Raymond Alf Museum of Paleontology** **Los Angeles Natural History Museum** **San Bernardino County Museum** *San Diego Natural History Museum* Pollack Library Cal State Fullerton
Colorado	Dinosaur Resource Center Florissant Fossil Beds National Monument Dinosaur Depot
Connecticut	Dinosaur State Park
Florida	*Okaloosa Walton College*
Illinois	**Field Museum** *Burpee Museum* Chicago Children's Museum Dave's Rock Shop
Maryland	*Maryland Geological Survey* *Calvert Marine Museum*
Massachusetts	**Harvard Museum of Natural History** Amhurst College Museum of Natural History
New Jersey	Morris Museum Rutgers Geology Museum Natural History Museum of Princeton
North Carolina	Aurora Fossil Museum
Ohio	*Caesar Creek State Park* *Cincinnati Museum Center* *Cleveland Natural History Museum* **McKinley Presidential Library and Museum** Ohio State University
Oklahoma	Northwestern Oklahoma State University Sam Noble Museum of Natural History
Pennsylvania	**State Museum of Pennsylvania** *Carnegie Museum of Natural History* Academy of Natural Sciences
Texas	University of Texas El Paso Centennial Museum El Paso Museum of Archaeology
Vermont	*Perkins Geology Museum* *Middlebury College*
Virginia	Virginia Living Museum
Washington, D.C.	**Smithsonian Museum of Natural History**
West Virginia	*West Virginia Geological Survey State Museum*

Table 1 (continued)

Outside United States		
	Bahamas	Dan's Cave Hole-in-the-Wall National Museum of the Bahamas
	Mexico	National Mexican Museum of Natural History
	Puerto Rico	University of Puerto Rico Las Cabezas de San Juan

[a]2007 only. [b]*2008 only (italics)*. [c]**Both 2007 and 2008 (bold)**.

Figure 2. Famous museums, such as the Field Museum in Chicago, Illinois (left) were included in students' research. However, students who were not in geographic proximity to the larger, more famous sites were still able to find local museums and informal education environments that featured fossils. The Aurora Fossil Museum (right) is located in North Carolina.

In general, project submissions for both semesters were excellent, and students demonstrated knowledge of the paleontology content, as well as effective application and synthesis of the material. In both years, the photographed specimens were representative of all the invertebrate phyla, and several vertebrate orders and plant divisions. Figure 3 shows a representation of included fossils. Ichnofossils, especially track ways, were popular fossil choices for both classes. Not only were fossils diverse in their morphology, but both 2007 and 2008 practicing teachers photographed specimens from the Precambrian through the Pleistocene Epoch, encompassing most of the Earth's geologic history.

Paleoenvironment analysis and inclusion of local environments. Because the practicing teachers chose informal learning sites within driving distance, the majority of these informal sites included local area fossils, and our practicing teachers chose to incorporate them. In the paleoenvironmental analyses, the local environment was always included by our practicing teachers. The environments of deposition included both terrestrial and marine environments. Because our practicing teachers reside in several very different geographic areas, the fossils, paleoenvironments, and geologic times represented were quite diverse. Tar seeps, coal swamps, glacial moraines, lacustrine, turbid marine, deep marine, and reef environments--from a wide range of geologic time--were discussed as paleoenvironments by our practicing teachers.

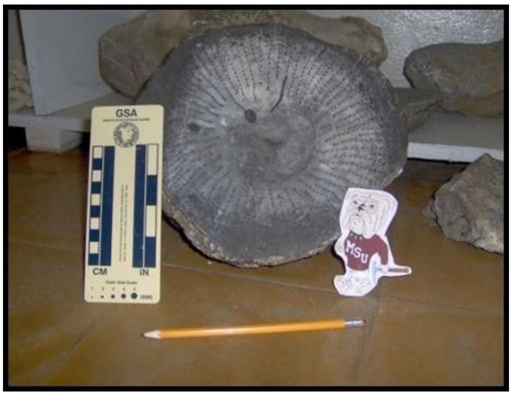

Figure 3. Fossils represented all major phyla, and ranged from Precambrian to Pleistocene in age. Many fossils selected by practicing teachers for inclusion were often collected within their local geographic areas. These included a Pleistocene bat skull, Phylum Chordata (left), courtesy of Nancy Albury and (right) a Puerto Rican rudist (an extinct bivalve, Phylum Mollusca, that contributed heavily to Cretaceous reefs of the US Gulf Coast) , courtesy of Janette Stewart.

Practicing teachers' mini-units and activity development. The practicing teachers developed a variety of informal and student-centered activities for their own classrooms. Both 2007 and 2008 practicing teachers integrated informal site visits in their mini-units, with the exception of one teacher who noted that her district no longer allowed teachers to take classes outside the school on "field trips." Informal field excursions had a common characteristic: Teachers focused upon a select group of fossils, a geologic time period, and/or an environment of deposition. Scavenger hunts at local museums were a popular activity utilized by the teachers. An example of a practicing teacher's activity that focused on fossils from the Academy of Sciences in Philadelphia, Pennsylvania is presented in Figure 4.

Practicing teachers also developed a variety of classroom assignments that included dichotomous key use, hands-on ichnofossil identification, fossilization experimentation, and Podcast development. Innovative assignments were in abundance, with geological time line "era menus," paleoenvironment dioramas and murals, and "travel brochures." A "Paleo Paparazzi" focused upon "stratigraphical fossil celebrities." Several teachers developed activities with Carboniferous swamps. Students would investigate the original ecosystem, fossilization processes, coal formation, and the economics of coal in the modern age.

In order to evaluate their students' knowledge gain, our practicing teachers developed a wide spectrum of assessment tools. Traditional test items (examinations), cooperative mural development, group multimedia presentations, and portfolios were all represented.

Teacher perceptions of informal sites in Earth Science classrooms. Most of the practicing teachers participated in the electronic end-of-semester survey (n = 13 in 2007 and n = 11 in 2008). The purpose of this survey was to improve our online classroom through feedback gathered from our practicing teachers. Questions were anonymous and open-ended, and included the practicing teachers' identification of the assets in our online classroom, the perceived problems that should be immediately addressed, and opinions on application activities and other assessment methods. We also probed our practicing teachers for opinions on each of the quarterly application activities. Questions specific to the informal site application included 1) teachers perceived value and impact of informal science education to formal geoscience learning through fossils and site visits, 2) teachers' perceived interest of their own students for informal activities and informal investigations, and 3) problems or potential difficulties in informal site investigation and paleoenvironmental interpretation.

"CALLING ALL CARS! CALLING ALL CARS"

In this assignment you will write a 15-second "all points bulletin" (APB) alerting police and the general public to be on the lookout for an escaped organism from the Academy of the Natural Sciences. In your APB you must address the following:

1) Name of specimen and any known aliases
2) General description
3) When it was last seen
4) Where it was last seen (region, not the Academy!)
5) Where it likes to "hang out"
6) If it should be considered dangerous and to what/whom
7) Species it could easily be confused with

An example is below (this organism is not from the Academy).

Calling all cars, calling all cars! Be on the look out for Apatosaurus ajax, also known as Brontosaurus ajax! This saurapod dinosaur is 15 feet tall at the hips and about 70 feet long! It weighs about 40 tons. It has a long neck, small head, long tail and walks on four legs. It was last seen 140 million years ago in the American West It is probably headed toward a forested riverbank where it likes to graze on the tops of trees. Even though it is not a meat eater, it should be approached with caution. It could easily crush an entire building with its foot or tail. Luckily it has a very small brain and should be spotted easily. It could be confused with Brachiosaurus. Stay on the look-out. Over and out!

Figure 4. Many practicing teachers utilized the informal learning sites and local fossils in their classroom units. A characterizing trait of the incorporation of informal sites was that the activities were directed and focused upon specific organisms, geologic time periods, or environments. This activity, courtesy of Amy Carpinelli, was developed for the Academy of Natural Sciences in Philadelphia, Pennsylvania.

We used Neuendorf's (2002) content analysis guidelines to code the anonymous responses from both semesters, and three stable themes emerged. The practicing teachers consistently noted that 1) the informal sites and local fossils affirmed the importance of the local environment and put it into a larger context with regards to science content, 2) directed student activities within informal education sites can maximize learning, and 3) informal sites integrate information and provide an interdisciplinary “big picture” for students.

Final examination scores attested to teachers’ understanding of paleontology and paleoecology content presented in the course. Our practicing teachers also were overwhelmingly positive about the informal learning assignment. The local environment--investigated through local fossils and within local informal sites--appeared to be a key ingredient for the assignment’s success. Several practicing teachers remarked that the informal project facilitated investigation, not only of local fossils and the former paleoenvironment, but also strengthened connections with the local community. Comments included: “I got to see a lot of my area” and “[the project] allowed me to focus on significant local fossils . . . . I began looking and asking questions that led to a larger question of a particular environment not explored.” One practicing 2008 teacher, who was chronicling her informal investigation and paleoenvironmental reconstruction within her classroom, remarked: “When I have told my students about it, they are most interested in the fact that I have recreated OUR area, not some unknown area far away.” Another teacher noted that students “hardly make the effort to use their community’s resources and this could be the obligation they need to do just that.”

Our practicing teachers acknowledged that directed activities in informal environments were an important component to maximize learning. A 2008 teacher noted that a directed activity “transforms a casual stroll through a museum to a focused visit. I also think by creating some guided specificity the overload factor is reduced.” The 2007 teachers also thought the focus upon a paleoenvironment, a geologic period, and specific fossils were important, and that their own students “would enjoy it and it would be a good learning experience.” Another commented that “students would enjoy learning about fossils and environment through the use of a museum.”

Our practicing Earth Science teachers consistently noted that the informal education assignment synthesized the content of the course; not only for them personally, but that the informal sites had great potential to do this within their own classrooms. Fossil investigation at local sites addressed the geology (Earth’s history), as well as biology and chemistry in the paleoenvironment reconstructions. Additionally, local human history could be incorporated with local informal sites. The 2007 teacher comments included “it brought everything in the course together and it made more sense. It was like a light bulb coming on” and “I learned the most [from the informal environments].” The 2008 students concurred that the informal site investigations and paleoenvironmental reconstructions require “more synthesis and application of information,” and that the assignment “helped me review and synthesize what I had encountered throughout the course!” The investigation was interdisciplinary, and “forced us to incorporate many different disciplines into a focused unit.”

Conclusions and Implications

When asked in the end-of-year survey to identify their favorite part of the History of Life course, 70% of 2007 practicing teachers and 90% of 2008 teachers ranked the informal learning site investigation and mini-unit development as their favorite activity. All teachers were able to develop activities and mini-units that could be utilized within their own classrooms. The informal education application exercises allowed our practicing teachers to synthesize History of Life course material and consolidate learning through an investigation of local sites. Our practicing teachers were consistent in acknowledging that informal education provided an effective means to learn outside of the classroom.

We were pleasantly surprised to see the level of affirmation for local informal site investigation within the teachers' individual classrooms. Although the second part of our assignment involved the development of a mini-unit for teachers' individual classrooms, teachers not only completed the activity, but in turn established directed local field excursions for their own students. The local environment appears to be a key factor: Exploring past local environments through local fossils, within local informal sites, allows a teacher to build upon the "common ground" and experiences of students. Investigation with local informal sites provides a familiar base to learners, and it can be a platform upon which to scaffold additional knowledge. Furthermore, local research provides context to the material presented in the classroom. This was applicable not only in our online classroom, but in practicing teachers' individual classrooms as well.

Our practicing teachers, with greater collective informal educational experience than we have, noted how important directed study was within an informal site during a site visit or investigation. Without guided activities, students might have difficulty focusing on the exhibits within a large museum or nature park. Assorted, although interesting, facts might be overwhelming, and not completely conducive to learning if not presented within a context that the students can understand, and which can be integrated into an existing knowledge base.

Informal field excursions are important to augment and enhance traditional classroom learning. Our practicing teachers noted that site visits "make the topic come to life. Field trips are wonderful." Informal sites can extend learning. As one teacher noted, "informal sites are great places to stimulate and reinforce what is done in the classroom." Another teacher stated that informal sites reinforce the concept that learning is not limited to classrooms: "Students would absolutely love this. Students can begin to explore geologic information outside of the classroom and see that people other than teachers can be purveyors of knowledge."

Our teachers also identified that their students have great enthusiasm for field excursions: "I can tell you the level of excitement my students have for their field trip is awesome! When I announce the dates, usually that day 6 students have already deposited their money for the bus!" Another remarked: "Anytime that we are able to actually get out and 'do' science they get excited."

Capitalizing on students' enthusiasm, focusing student research in an informal learning site, and integrating several disciplines within site investigation sounds like a recipe for science success to us. We propose that our exploratory research has potential implications beyond the use of local fossils and informal sites within Earth Science classrooms. Informal educational sites can be used to extend and enhance learning potential outside formal classrooms if lessons are designed to 1) integrate the local environment, 2) provide interdisciplinary study opportunities, and 3) focus upon a limited topic of organisms, environment, or other specific theme.

Perhaps one of our practicing teachers best summed up the potential impact of informal learning as follows: "I have seen some of my students from years ago and the one thing they remember is the field trip that I take them on. That is what I like to think is a life-long learning experience!" We invite practicing teachers to capitalize upon the possibilities for informal science learning within their local communities.

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