Building an Effective and Affordable K–12 Geoscience Outreach Program From the Ground Up: A Simple Model for Universities

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ABSTRACT

University earth science departments seeking to establish meaningful geoscience outreach programs often pursue large-scale, grant-funded programs. Although this type of outreach is highly successful, it is also extremely costly, and grant funding can be difficult to secure. Here, we present the Geoscience Education Outreach Program (GEOP), a small-scale, very affordable model tested for 5 y in the Department of Earth Sciences at the University of California, Riverside (UCR). GEOP provides in-class presentations for local K–8 classrooms; science, technology, engineering, and mathematics mentoring for middle and high school students; day-long events on the UCR campus for middle and high school students; and it allows UCR Department of Earth Sciences to participate in a wide range of community events. The program is managed by UCR graduate students, affects ~4,000 people (K–12 students, UCR students, the Riverside community at large) and operates for less than $3,000 U.S. annually. The GEOP model prioritizes simplicity, flexibility, and affordability to best meet the educational needs of Riverside County, California. © *2016 National Association of Geoscience Teachers*. [DOI: 10.5408/15-100.1]

Key words: K–12 outreach, mentoring, community education

INTRODUCTION

In 2009, members of the Department of Earth Sciences at the University of California, Riverside (UCR), made a collective decision to engage more effectively with the Riverside community at large. Riverside County, where UCR is located, is one of the most densely populated and socioeconomically disadvantaged counties in California. According to the 2010 U.S. Census, 46.7% of Riverside County's 2.3 million residents are Hispanic, and 39.8% of households are non-English speaking. Riverside County's median household income is 10% lower than the California average, and children are highly likely to attend a Title 1 (high poverty) school. Communities like these are more vulnerable to dangerous geologic events, such as earthquakes (common in Southern California) and the local effects of climate change (such as extreme heat waves and drought) because they lack both access to important geoscience information and the economic ability to recover from damaging events (Morello-Frosch et al., 2009). As geoscience experts, we were in an ideal position to improve geoscience communication in Riverside County.

We acted in response to our social responsibility as geoscientists and to the necessity of geoscience education and outreach in K–12 classrooms that has been further highlighted by several recent studies. These studies project a severe workforce shortfall in the coming decades and a failure to successfully recruit new geoscience students (see National Research Council, 2010, 2011; Wilson, 2014; Zeigler and Camarota, 2014). This failure to recruit has several causes. School districts across the nation have been reducing or eliminating geoscience curriculum, thereby removing the opportunity for K–12 students to gain exposure to geoscience. In California, public school science course offerings are largely dictated by the University of California (UC) admissions requirements. Students are required to take "two years (three years recommended) of laboratory science providing fundamental knowledge in two of these three foundational subjects: biology, chemistry, and physics" (UC Admissions Requirements; University of California, Riverside Office of Admissions, 2015). Because Earth Science is not a UC-approved laboratory science course, high-school students have little incentive to enroll in Earth Science courses, even if they are offered. Riverside Unified School District (RUSD), the district in which UCR is located, is gradually eliminating Earth Science courses. Consequently, students only gain exposure to the geosciences if they elect to take Advanced Placement Environmental Sciences.

The reduction in course offerings from public school science curriculum is not unique to the Earth Sciences and not unique to California and, in fact, was recognized as two of five "hidden" threats facing science education by Huntoon et al. (2012), namely state educational standards not emphasizing key concepts and offering limited course options. The lack of high-school level course offerings in the Riverside area has likely contributed to low recruitment. Similarly, a lack of exposure to a discipline at the high-school level has a negative effect on that discipline's ability to attract outstanding students to college majors and careers (Huntoon et al., 2012).

These geoscience recruitment woes are further compounded by a severe lack of diversity within the field. According to the *2014 Status of the Geoscience Workforce* from the American Geosciences Institute (AGI; Wilson, 2014), geoscience programs are the least diverse in science, technology, engineering, and mathematics (STEM) fields, with only 7% of students from underrepresented minorities compared with 30% across all STEM fields (NSF, 2015). Despite the fact that studies have identified the underlying causes of the geosciences' failure to recruit students (factors such as lack of awareness of career opportunities, under-

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TABLE I: Demographic breakdown by ethnicity for Riverside County, UCR, the State of California, and the United States, showing the high Hispanic population of Riverside County compared with California and the United States.

Ethnicity	Riverside County,[1] %	UCR,[2] %	CA,[1] %	USA,[1] %
Hispanic or Latino	46.9	32.1	38.4	17.1
White, not Hispanic	38.0	17.0	39.0	62.6
African American	7.0	8.7	6.6	13.2
Asian or Pacific Islander	7.1	35.4	14.6	5.5
Native American	1.9	0.5	1.7	1.2
Other	3.3	8.7	3.7	2.4

[1]U.S. Census Bureau, 2010.
[2]UCR Office of Admissions.

preparation in STEM coursework, lack of familial support, and fewer opportunities for engagement in outdoor activities, such as hiking and camping; O'Connell and Holmes, 2011; Stokes et al., 2014), our field has continuously failed to recruit young geoscientists from minority communities. As national demographics grow increasingly diverse, we must develop effective recruitment strategies targeted toward minority students if we are to avoid the projected worker shortfall. Without an increase in recruitment, AGI predicts that this worker shortfall may grow as large as 135,000 by the year 2022 (Wilson, 2014).

To address these issues, the UCR Department of Earth Sciences established the Geoscience Education Outreach Program (GEOP). GEOP is organized by Earth Science graduate students, operates on a budget of less than U.S. $3,000 annually, and affects thousands of Riverside County residents (K–12 students and adults). Although most of the outreach events in GEOP are in-class presentations in K–8 classrooms, the program is designed with enough flexibility to accommodate the wide range of needs in Riverside County. The program provides mentoring for middle and high-school students, activities and education for school groups, visits to the UCR campus, community events, and easy access to geoscience experts. Our success proves that GEOP is a workable model that can be recreated in many university Earth Sciences departments and easily tailored to different types of audiences (underrepresented minority students, rural communities, etc.).

PROGRAM OBJECTIVES

In designing GEOP, we identified five primary objectives:

1. Provide geoscience content to supplement existing K–12 STEM curricula,
2. Expose K–12 students to geoscience content (K–8) and career opportunities (6th–12th),
3. Provide opportunities for high-school students to engage in geoscience research,
4. Strengthen the geoscience education pipeline in the region by building connections between school districts, community colleges, and UC Riverside, and
5. Strengthen connections with local school districts and the Riverside community at large so that our department can provide necessary geoscience information on relevant topics (earthquakes and other natural hazards, global climate change) and improve science literacy in our surrounding community

INSTITUTIONAL BACKGROUNDS

University of California, Riverside

UCR is a federally designated, Hispanic-serving research university in Southern California, with a student-body population of 21,200. Institutions are designated *Hispanic-serving*, when they serve a study-body population that is at, or above, 25% Hispanic and more than 50% of students are low income (Bordes and Arredondo, 2005). UCR is the most diverse of the 10 UC campuses (Table I) and has developed several highly effective programs to ensure the success of underrepresented minority students (41.3% of the student body), first-generation college students (45% of the student body), and low-income students (56% of the student body, based on Pell Grant Awards). Because of these programs, UCR is a national leader in successfully graduating underserved students. At UCR, graduation rates for these historically disadvantaged groups are equal to graduation rates overall and to national graduation rates for all students (Department of Education, 2015 College Scorecard). The *Washington Monthly* annual list of top universities (National University Rankings, 2015), which measures social mobility and community service in addition to academic research, ranked UCR second overall in 2015. Most of the UCR undergraduates, like most of the inhabitants of the City of Riverside, come from Southern California communities (Riverside, San Bernardino, Los Angeles, and Orange and San Diego counties).

UC is fully committed to meeting the educational needs of Californians and has cemented this commitment in the UC Board of Regents *Policy on University of California Diversity Statement*, noting that "The University particularly acknowledges the acute need to remove barriers to the recruitment, retention, and advancement of talented students, faculty, and staff from historically excluded populations who are currently underrepresented" (University of California, Board of Regents, 2010). In the UCR Department of Earth Sciences, we consider a thriving outreach program to be a part of the university's commitment.

RUSD and Other Surrounding Districts

RUSD is bordered by several other districts (Moreno Valley School District, Val Verde School District, Jurupa School District, Alvord School District). All of these local school districts are majority Hispanic and serve a high population of low-income students (see Table I). Although STEM education is valued and promoted in these districts, schools are underfunded, and students lack opportunities to engage in STEM learning. GEOP has been designed to best serve the student populations in these local districts; therefore, all events and activities are free, and public education events are presented in English and Spanish.

PROJECT DESIGN

In developing the GEOP model, our goal was to provide the most services possible on our very limited budget. GEOP is designed around several hands-on learning activities. We also considered the demographics of our target audiences and designed outreach products that best served the largely Hispanic and often low-income student population of Riverside County. In addition, we wanted GEOP to benefit everyone involved in the program, so we considered how the program would affect not only K–12 students but also their teachers and the volunteers presenting the GEOP programming.

GEOP project design was guided by the theoretical frameworks of Levine et al. (2007) and Nora (2005), which both suggest methods for improving recruitment and retention of underrepresented minority students in STEM fields. The Levine Framework, which focuses specifically on the geosciences, examines K–16 students' critical incidents of engagement with the geosciences to determine what factors influence decision making at educational junctures (high school to college, 2-y college to university, university to graduate school or workforce). They find that factors such as course selection, extracurricular activities, familial involvement, geoscience awareness, and effective instruction were most important for K–12 students. The Levine Framework also suggests that effective interventions at each stage of education could improve recruitment into the geoscience education pipeline. The Nora Framework, which considers STEM fields as a whole, rather than specifically focusing on a single field, suggests that Hispanic students are more likely to bring precollege experiences to college. Precollege experiences, such as prior academic achievement or first-generation status, function as "pull factors" and cause students to either "pull away from" or get "drawn into" a STEM major. Both frameworks suggest that exposure to, and engagement with, STEM fields early in a student's academic career can influence their interest in that field when they reach college.

Several studies have examined the effect of different types of interventions included in GEOP, such as short-duration classroom-outreach events and mentoring (see Tsui, 2007). For example, Laursen et al. (2007) evaluated the effect of short-duration classroom-outreach events through interviews with teachers, students, and presenters. When asked about changes in interest and engagement in science, 88% of teachers and 92% of students reported positive gains. When asked about new views of science and scientists, 44% of teachers and 100% of students reported positive gains. Finally, when asked about student understanding of science concepts and their relevance to real life, 38% of teachers and 33% of students reported positive gains. When evaluating the effect of these events on the presenters, Laursen et al. (2007) found that 83% reported a gain in skills (teaching communication and management), 92% reported a gain in understanding (particularly in issues surrounding education and diversity), 83% reported a personal gain (such as growth in confidence and intrinsic or emotional rewards), and 96% reported career gains (such as transferable knowledge and skills or resume building). Andrews et al. (2005) also found that outreach providers benefited from participation, and graduate student participants were often motivated by the opportunity to improve teaching and communication skills. The National Science Foundation NSF GK–12 Program, which connected graduate teaching fellows (who are training to become research scientists) from State University of New York System, Binghamton, with 3rd–6th grade classrooms in the Binghamton City School District, showed that this connection benefited all involved (Stamp and O'Brien, 2005). Teachers learned new content, students' attitudes toward science improved, and graduate teaching fellows gained teaching experience.

Mentoring has been proven repeatedly to increase student engagement and success in STEM fields (see Santos and Reigadas, 2002; Bordes and Arredondo, 2005; Huntoon and Lane, 2007; Cole and Espinoza, 2008; Griffin et al., 2010; Charlevoix and Morris, 2014). This is especially true for minority students, who often feel alienated or unfit to pursue an education or a career in the sciences. Several studies have documented the benefits mentoring has provided to minority students, including higher grade-point averages, lower attrition, increased self-efficacy, and better-defined academic goals (Arnold, 1993; Thile and Matt, 1995; Schwitzer and Thomas, 1998; Santos and Reigadas, 2002). In an examination of the role of mentoring of Latina and Latino students' success in college, Bordes and Arredondo (2005) reported that mentoring improved student experiences during their first year of college by increasing feelings of cultural congruity. Furthermore, although previous studies have suggested that mentors are more effective if they share the same cultural background (e.g., Santos and Reigadas, 2002; Charlevoix and Morris, 2014), Bordes and Arredondo (2005) found that the cultural background of the mentor had no significant difference in student success. In a meta-analysis of 55 evaluations of youth mentoring programs, DuBois et al. (2002) found that, when empirically derived best-practices are employed and when strong relationships between mentor and student are formed, mentoring programs can have a strong, positive effect on a student's success. This effect was strongest for students from disadvantaged backgrounds.

GEOP is overseen by the chair of the Department of Earth Sciences and a graduate student program manager. The program manager, who is selected yearly, is responsible for handling incoming requests from K–12 teachers, school administrators, and community event organizers. Although in-class presentations are standardized, other events may require personalization, so the program manager works with organizers and other community liaisons to determine how best to meet their needs. The program manager is also responsible for recruiting and training outreach volunteers, maintaining outreach kits and other teaching materials, and publicizing the program within local school districts and on the department's Web site.

The program manager ultimately serves as the link between the university and the outreach audiences (see Fig. 1). Because the graduate-student program manager serves such a crucial role, the Department of Earth Sciences has

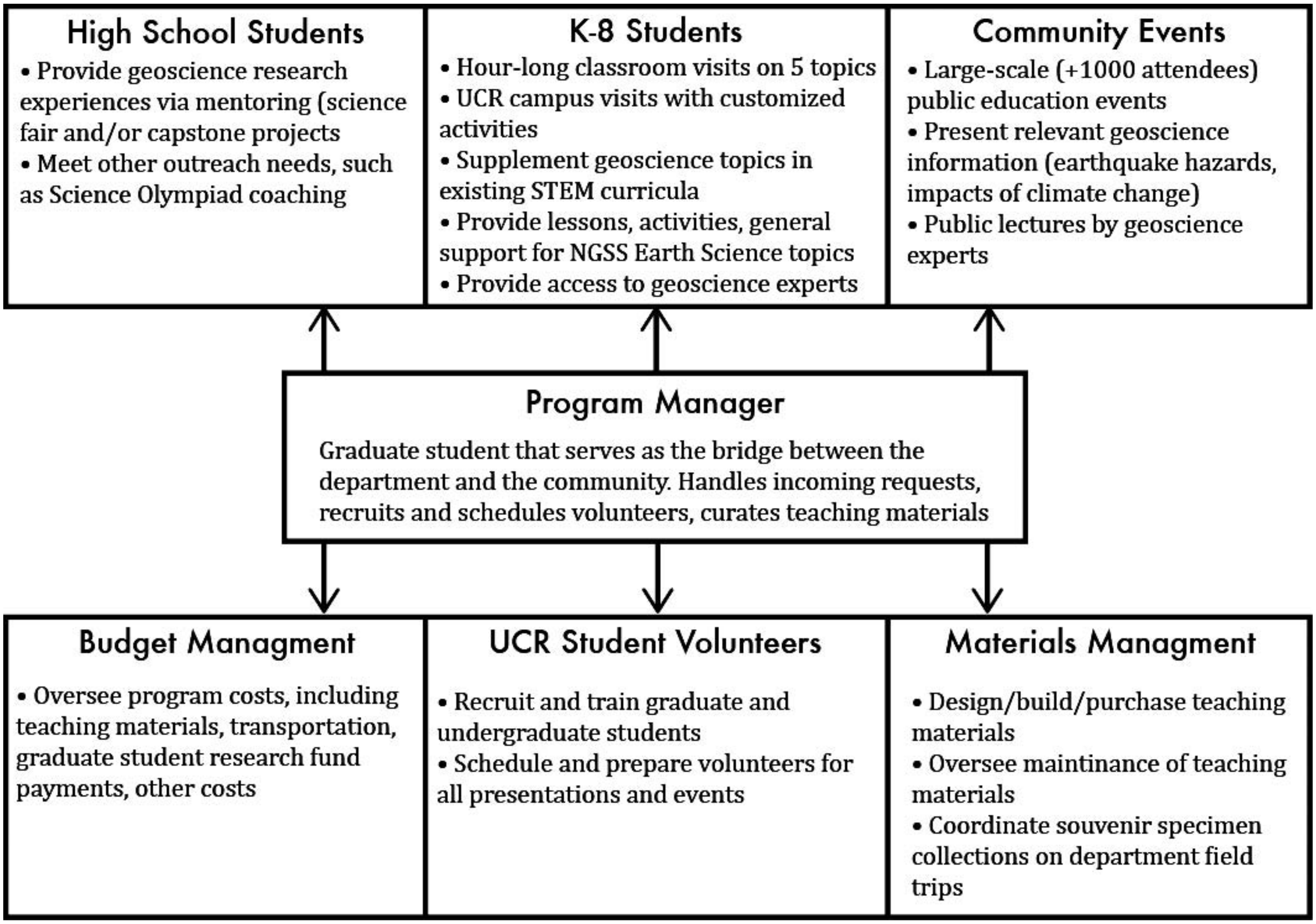

FIGURE 1: GEOP design. The program manager functions as the link between outreach communities and the department.

awarded the program manager one quarter of the department fellowship for each year that he or she servers as manager. The manager does not receive monetary compensation during the remaining two quarters of service, but graduate students serving in this role have been willing to volunteer their time for the experience and professional development they receive while in this position. (See "Implementation" below for alternative funding models).

UCR Participant Recruitment and Training

GEOP relies heavily on graduate and undergraduate student involvement. At the beginning of each academic year, the program manager recruits graduate students through direct conversations with new graduate students, announcements at department meetings and seminars, and e-mail messages. Undergraduate student recruitment is focused on upper-level geology majors (typically juniors and seniors), who are recruited by the program manager through announcements given in upper-division geology classes and at meetings of the Geology Club.

During the past 6 y, nearly all (89%) Earth Science graduate students and most faculty (66%) have participated in GEOP events. This extremely high level of participation is likely due to the overall culture of service that permeates the department, UCR, and the UC. GEOP has been supported and promoted by all three department chairs (Mary Droser, Richard Minnich, and current chair, David Oglesby), and faculty encourage their graduate students to participate in the program. Incidentally, GEOP's success has served as excellent leverage in garnering monetary donations to the department, which are then used to fund the program.

GEOP presenters are trained by the program manager. Training is always personalized and varies for each type of outreach event. For in-class presentations and campus visits, the program manager will acquaint the presenter with tailored educational materials, including presentation slides, specimens, activities, and souvenirs. The program manager will also brief the presenter on the grade level and background knowledge the class may possess and on any special requests made by the teacher. First-time presenters may request to be scheduled with an experienced partner. Finally, presenters are encouraged to adapt the presentation as they see fit. GEOP does not provide a script for presentations; they are designed to be flexible enough to meet each classroom's specific needs. Mentors to individual students are briefed on the student's academic background, interests, and mentoring needs (science fair or capstone project). Throughout the mentoring relationship, the program manager will track progress and can provide resources and suggestions on an as-needed basis. For large-scale

TABLE II: Breakdown of annual spending by event type. Annual costs average U.S. $2,055.00 (U.S. $0.66 per person). Because GEOP events are scheduled by request, the number of events fluctuates each year, depending on the number of requests. The 2014–2015 budget is not final as of the writing of this article and is expected to match the budget of 2013–2014.

Event Type	No. of People Affected				
	2010–2011	**2011–2012**	**2012–2013**	**2013–2014**	**2014–2015**
In-class presentations	1440	2250	2250	720	480
On-campus groups	0	0	300	300	300
Other school outreach	100	100	100	100	525
Mentoring	0	35	2	2	5
Community events	0	0	5,400	6,200	5,200
Total No.	1,540	2,385	8,052	7,322	6,509
Total budget, U.S. $	950.00	1,775.00	2,800.00	2,900.00	1,850.00
Per-person spending, U.S. $	0.62	0.74	0.35	0.40	1.23

community events, volunteers are trained as a group, and first-time volunteers are paired or placed in a team with experienced volunteers so that they can also learn during the course of the event.

In-Class Presentations (K–8)

Hour-long, in-class outreach presentations form the basis of the GEOP. These presentations serve three purposes: (1) to expose elementary-school students to the geosciences, (2) to supplement teachers' existing STEM curriculum, and (3) to raise students' awareness of career opportunities in the geosciences and to foment the possibility of future recruitment of geoscientists. Engagement in STEM topics early in a student's academic career has been shown to be crucial in the later recruitment of STEM majors and professions, especially for Hispanic students (Tyson et al., 2007; Crisp et al., 2009). GEOP in-class presentations serve as an engagement opportunity, especially as geoscience course offerings are removed from districts in Riverside County.

In-class presentations are given by UCR graduate and undergraduate students. Teachers select one of five prefabricated presentation topics: (1) rocks and minerals, (2) fossils, (3) earthquakes, (4) volcanoes, and (5) climate change. These topics were chosen to provide a wide range of geoscience material that can be broadly applied to K–8 curriculum, as suggested by UCR faculty and an informal survey of RUSD teachers. Presentations are adjusted to grade level, each class's background knowledge, and each teacher's STEM curriculum. The program manager communicates with teachers to assess these factors. Because of this tailoring, a rocks and mineral presentation for 1st-grade students would be much simpler than it would be for 5h-grade students, who would have prior knowledge of the structure of the Earth and the rock cycle. All five presentations are structured around experiential activities, which have been shown to be highly effective in engaging students in the geosciences (Van der Hoeven Kraft et al., 2011). Each presentation's activities and learning outcomes are detailed in Table II. As California public schools have begun to transition to the Next-Generation Science Standards (NGSS), we have adjusted our presentations to better meet NGSS curricula.

Teachers are often actively engaged in the presentations because they are tailored to each teacher's specific requests. Teachers not only watch the presentation with their students, examine specimens, and participate in learning activities but also include the presentation in their own teaching by asking the class follow-up questions and assigning written reflections about the presentation.

At the beginning of each presentation, the presenter introduces him or herself and gives a brief personal history on their love of science, education, and career goals. At the end of each presentation, the presenter gives a short plug for the geosciences by suggesting that if students enjoyed the presentation, they should consider taking a geology class or even pursuing a career in the geosciences. The presenter points out that there are many excellent opportunities available in Southern California for students with degrees in geology. This final moment is key in raising awareness, as suggested by Levine et al. (2007). In addition, students are given a small specimen as a souvenir to launch their rock and mineral collection (see Table III). UCR geology students collect the program's souvenir specimens on department field trips. We have collected serpentinite from fault zones in northern California, scoria and obsidian from Inyo County in eastern California, sulfur from Mono County in eastern California, and tourmaline and quartz from San Diego County. We also receive mineral and fossil donations from amateur collectors. Collecting specimens from Californian localities has the benefits of being low cost (department field trips already visit these sites each year) and of creating a place-based connection for the students who receive them as souvenirs.

In-class presentations are offered free to local classrooms (within 20 miles of UCR campus). Graduate student presenters receive $25 per presentation. This fee is placed in a research fund that can be used to purchase laboratory or field equipment or to reimburse conference fees or other research costs. In this way, GEOP also helps to promote and fund graduate student research in the department. Undergraduates participate on a purely volunteer basis. If no students are available to do the presentation, the program manager will step in. We have found that $25 per presentation provides enough incentive to recruit graduate students without exhausting our small budget. This program costs U.S. $1,875 annually (75 presentations per year) (see Table IV). We have also found that the double benefit of funding outreach and student research has made securing donor funding for the program easier because donors feel their money is going twice as far.

TABLE III: Prefabricated presentations for K–6 classrooms, showing each subject's activities and anticipated learning outcomes.

Presentation Topic	Activity	Learning Outcome
Rocks and minerals	1. Examine and handle samples of the three rock types (igneous, sedimentary, metamorphic)	Students learn to identify the three rock types based on characteristics (composition, texture)
	2. Compare mineral specimens to classroom objects that contain those minerals	Minerals are an important resource; students interact with minerals every day
Fossils	1. Compare five fossil teeth (*Carcharodon*, *Tyrannosaurus*, *Smilodon*, *Mammuthus*, *Equus*)	Tooth structure can be used to interpret the diet of extinct animals
	2. Examine fossil specimens representing the major stages of evolution of life (marine invertebrates, dinosaurs, Pleistocene megafauna)	Fossils can be used to interpret ancient life; life has evolved greatly throughout the Phanerozoic, and fossils are more than just dinosaur bones
Earthquakes	1. Discussion of personal earthquake experiences	Earthquakes are common in Southern California; earthquakes are a natural hazard that must be understood by people living in active fault zones
	2. Generate energy waves with a slinky	The waves generated by earthquakes move differently and are felt differently when they impact surfaces/structures
	3. Quake catcher network demonstration	Earthquakes can be tracked using very simple technology managed by students (citizen science)
	4. Earthquake drill	Students should drop, cover, and hold on during an earthquake
Volcanoes	1. Examine specimens of volcanic rock (obsidian, pumice, scoria, granite)	Rock characteristics (grain size, cleavage, composition) can indicate the formation history of that rock
Climate Change	1. Discussion of climate versus weather in Riverside County	Weather is the current atmospheric conditions and can change rapidly (hourly, daily), whereas climate is a long-term average of weather and changes very slowly
	2. Test the temperature of different-colored surfaces	Color correlates with albedo, and surfaces with a high albedo reflect away solar energy before it can be absorbed and heat the surface
	3. Calculate your carbon footprint	Everyday activities consume energy, which leads to emissions of GHGs. Small changes in daily behavior can reduce GHG emissions
	4. Bottle atmospheres	When sodium bicarbonate is added to water, it produces carbon dioxide. Increased carbon dioxide causes temperature in the bottle to rise in comparison to the control bottle

Presentation 1: Rocks and Minerals

The rocks and minerals presentation is designed to introduce students to basic geologic concepts, including the structure of the Earth (crust, mantle, core), plate tectonics, the three rock types (igneous, sedimentary, metamorphic), the rock cycle, and minerals and their role in creating common objects and materials. The presentation begins with a very short PowerPoint (Microsoft, Redmond, WA) presentation to introduce the structure of the Earth and the three rock types. During the presentation, hand samples of igneous, sedimentary, and metamorphic rocks are passed around the classroom. Then a "show-and-tell" session of ~25 mineral specimens are displayed, described, and passed around the classroom. Students are allowed to handle all specimens in the teaching kit. Depending on time and grade level, students may get to learn basic mineral identification by testing mineral hardness and streak color. The presentation concludes with a final question-and-answer session. Then students receive a mineral specimen souvenir. The rocks and minerals presentation is the most popular of our presentations (requested ~50% of the time) because it fits easily into existing K–6 STEM curricula.

Presentation 2: Fossils

The fossils presentation is designed to use a specimen collection of ~25 fossil to introduce students to the history of life on Earth. The presentation begins with a short (~10 min) lecture on what fossils are, how fossils form, and where paleontologists find fossils. The remainder of the presentation is spent doing a hands-on investigation of the fossil specimens. Some fossils are presented and passed around the classroom in a show-and-tell style. Others are presented to the students without description and students are asked to make interpretations based on what they see (morphology, structure, similarity to familiar or living organisms). During the examination, students are presented with five fossil teeth (*Tyrannosaurus*, *Carcharodon*, *Smilodon*, *Mammuthus*, and *Equus*) and asked to interpret what type of diet each animal would have had. Students examine tooth morphology, serration, and size before making interpretations. The

TABLE IV: Components of dedicated teaching kits for each in-class presentation topic and for community-outreach events.

Topic	Kit Components
Rocks and minerals	1. Rock samples: granite, obsidian, limestone, sandstone, coal, metamorphics
	2. Mineral samples: biotite, bornite, calcite, feldspar, galena, garnet, gypsum, halite, hanksite, hornblende, kyanite, labradorite, lepidolite, magnetite, malachite, muscovite, quartz, serpentine, sulfur, tourmaline
	3. Mineral identification kit (scratch kit, hardness scale, acid bottle, magnet)
	4. Souvenir specimen: any local rock or mineral currently available
Fossils	1. Sedimentary rock samples: sandstone, limestone
	2. Vertebrate specimens: Albertosaurus foot (cast), dinosaur caudal vertebra, dinosaur skin (cast)
	3. Invertebrate specimens: ammonite (Cretaceous), trilobite (Ordovician), sea urchin (Cretaceous), oyster (Cretaceous), orthocone cephalopods (Devonian)
	4. Teeth: Carcharodon megalodon, Tyrannosaurus rex, *Equus*, *Smilodon*, *Mammuthus jeffersonii*
	5. Other specimens: coprolite, trace fossils
	6. Souvenir specimen: small fossil (usually a brachiopod, gastropod, crinoid columnal)
Earthquakes	1. Fault demonstration table
	2. Slinky
	3. Quake catcher network demonstration
	4. Souvenir specimen: serpentinite (formed in fault zones)
Volcanoes	1. Volcanic rock specimens: obsidian, pumice, scoria, granite, pegmatite
	2. Souvenir specimen: obsidian, scoria, or pumice
Climate change	1. Albedo demonstration (black, white, blue, green plates and laser thermometer)
	2. Pizza box solar oven
	3. Souvenir specimen: any rock or mineral specimen currently available
Community events	1. Posters (climate change, earthquakes, other local natural hazards, in English and Spanish)
	2. Educational games (drought limbo, tornado twister, the carbon price is right)
	3. Interactive activities (test the albedo, light bulb comparisons)

presentation ends with a final question-and-answer session, and then, students are given a small fossil souvenir (typically a brachiopod or crinoid columnal).

Presentation 3: Earthquakes

The earthquakes presentation is designed to introduce students to earthquake processes (where they occur and what causes them) and hazards. The presentation begins with a discussion of personal earthquake experiences (“Have you ever felt an earthquake?” “What did it feel like?” “What did you do during the earthquake?”). Because they live in the San Andreas Fault Zone, all students have some personal experiences with earthquakes. After this discussion, the presentation continues with a short lecture on the structure of the Earth, plate tectonics, and earthquake processes. Students then learn about the four major types of energy waves generated by earthquakes (P-waves, S-waves, Raleigh waves, and Love waves) by creating wave movements with a slinky. Younger students (K–3) demonstrate the waves by linking hands and moving the wave down the chain of students. After this demonstration, students learn about historic and recent earthquakes (San Francisco 1906, Loma Prieta 1989, Northridge 1994, Haiti 2010, Nepal 2015). The presentation is concluded with a discussion of earthquake hazards. Students learn about the potential for a large earthquake in the San Andreas Fault Zone and practice what to do during an earthquake. Projections and drills are based on the Great California Shakeout (Earthquake Country Alliance, 2015).

Presentation 4: Volcanoes

The volcanoes presentation is designed to introduce students to volcanic processes (where and how they form), the major types of volcanoes (shield, composite, caldera, cinder cone), historic/famous volcanoes (Mt. St. Helens, Mt. Vesuvius, Mauna Loa), and volcanic hazards. Students examine six examples of volcanic rock and are asked to draw conclusions about their formation (cooling rate, intrusive/extrusive). The presentation is concluded with a discussion of volcanoes in the Western United States (especially Northern California) and a question and answer session.

Presentation 5: Global Climate Change

The global climate change presentation is designed to introduce the evidence for global climate change, the greenhouse effect and important greenhouse gases (GHGs), human civilization’s role in modern climate change, the concept of a carbon footprint, likely local effects of global climate change, and ways that students can get involved in mitigation efforts. The concepts presented in this presentation are more advanced and complex than the other four presentations, and the presentation has proven more successful among older students (5th–8th grade). The topics addressed in this presentation are conveyed via a combination of place-based discussion and experiential activities. For example, the climate in Riverside County is hot and dry (Mediterranean), with several +100°F (37.8°C) days in the summer months. Students relate well to everyday examples of the greenhouse effect and albedo (light-grey cement is cooler on bare feet than black asphalt) (see Table II). Students can also study the relative albedo of different-colored surfaces by measuring the temperature of black, white, green, and blue metal plates. If time permits, students can calculate their carbon footprint. This presentation is concluded with a discussion on solutions. Students are asked to think of changes they can make in their daily lives to reduce their carbon footprint.

School Trips to UCR Campus

Campus visits are an opportunity to expose a large number of students to a range of geoscience topics in a short amount of time. GEOP hosts two to five school-group visits to our department annually. School groups are typically ~100 middle-school students from a local school, but GEOP has also hosted elementary-school students, afterschool groups, and girl scout troops. Groups spend 2–4 h on campus. Each of these events is tailored to the needs of the visiting students, and each visit often has a focus (global climate change, earthquakes, paleontology). Large school groups are divided into small groups of 10–15 students, then the small groups rotate through five to seven "activity stations," spending 30 min at each. Activity stations focus on specific topics, so an example event that focused on paleontology may have six stations: (1) hands-on examination of the fossil kit (used for in-class presentations), (2) museum scavenger hunt, (3) tour of the paleontology laboratories, (4) rocks and minerals, (5) climate change in Southern California (what lived here during the last ice age?), and (6) paleontology jeopardy. A climate change–focused event would consist of six different stations: (1) what GHGs are and where they come from, (2) calculating your carbon footprint, (3) games (tornado twister and drought limbo), (4) bottle atmospheres, (5) testing the albedo, and (6) climate change jeopardy. Campus visits are typically staffed by a combination of undergraduate student volunteers and graduate students. Graduate students receive U.S. $25–$50 for their participation, depending on the length of the event.

Mentoring

Mentoring has been shown to be positive and highly effective in recruiting and retaining STEM students from underrepresented groups (DuBois et al., 2002; Griffin et al., 2010). These one-on-one interactions allow high-school students to engage in high-level research projects, to become familiarized with formal research settings like university laboratories, and to build personal relationships with scientists. All these activities have been shown to promote further engagement in the geosciences, such as choosing a geoscience-related major at a university, pursuing advanced degrees, and pursuing geoscience careers (Huntoon and Lane, 2007; Wilson et al., 2012).

GEOP has worked to provide mentors to local high-school students in whatever capacity teachers and school administrators deem most needed or useful. Most GEOP mentors have worked with high-school students on science fair projects on geoscience topics, but we have also provided mentors for year-long capstone projects and provided research opportunities in UCR Earth Science laboratories for interested high-school students.

Participation in Community Events

As part of GEOP's objective to strengthen our department's connections with the Riverside community at large and to improve science literacy in the region, we have committed to participating in a wide range of community events. Examples include the City of Riverside's *Long Night of Arts and Innovation*, a public event to showcase the best STEM and creative arts projects from local institutions; UCR's *ScotFest*, an annual homecoming festival for UCR students, alumni, and families; and UCR's *Odyssey of the Mind*, an education fair for elementary and middle-school students to explore the connections between STEM and art. Each of these events has thousands of participants and provides an excellent opportunity to educate the local community about relevant geoscience topics and issues, such as earthquakes and natural hazards or the effects of climate change.

GEOP has designed a permanent set of teaching materials for community events. Having a dedicated teaching kit for these types of events simplifies organization and reduces costs for the one-time expense of building the kit. We spent U.S. $1,000 on laminated (durable) posters and interactive games and activities (see Table III for a detailed breakdown of the kit). Community outreach events are staffed primarily by undergraduate student volunteers, although larger-scale events, such as the *Long Night of Arts and Innovation* (10,000+ visitors) may require graduate-student staff as well. In these cases, graduate students are compensated at U.S. $25.00–$50.00, depending on length of time.

Other Outreach

GEOP's flexibility is a key factor in its success. The program prioritizes an ability to meet the needs and requests of teachers, schools, school districts, and the community at large, and as a result, GEOP interacts with the citizens of Riverside County in a wide range of venues and capacities. For example, through GEOP, UCR Earth Sciences was able to provide four UCR graduate-student coaches for the 2014–2015 academic year Science Olympiad team at the Riverside STEM Academy (they coached three subjects: fossils, dynamic planet, and geologic mapping). Because the GEOP infrastructure was already in place, the GEOP coaches had abundant geoscience teaching materials readily available and received the standard $25 per coaching session.

OUTCOMES

In the past 6 y, GEOP has visited 238 K–8 classrooms, provided mentors to 41 high-school students, and hosted 900 students on field trips to the Earth Science Department. The program has sustained a presence at events hosted by the City of Riverside and community groups, and has provided coaches for RUSD Science Olympiad teams (for the fossils, dynamic planet and geologic mapping events). Ultimately, GEOP has engaged more than 5,000 people per year in the geosciences, and most of those engagements have been with underserved K–12 students. The program is well known among teachers in RUSD and other local school districts. In addition to bringing geoscience to the Riverside community, GEOP has proven a valuable resource for our department by providing opportunities for our graduate and undergraduate students to hone their teaching and science-communication skills and to engage with a diverse community.

Because GEOP comprises several different types of outreach events (many of which are unique or standalone events), evaluation data have been difficult to collect. We have conduced surveys at large public outreach events (*Refresh Riverside* and *Long Night of Arts and Innovation*), and we surveyed UCR undergraduate and graduate-student presenters. Both data sets are discussed below. For other types of outreach, we have provided case studies from the perspective of individual participants to illustrate the effect of each participant's interactions with GEOP. These case studies highlight the types of success GEOP has shown during the past 6 y.

Case Studies

Edgar Rodriguez–6th-Grade Science Teacher

Edgar Rodriguez is the 6th-grade science teacher at the Riverside STEM Academy (RUSD). After arranging GEOP presentations in 2011, Mr. Rodriguez decided to increase the geoscience component of his curriculum and worked with the GEOP program manager to design specialized activities for his classroom. These included a guided nature walk through the Box Springs Mountains Reserve above his campus, highlights of local geology, and annual class field trips to the UCR Department of Earth Sciences. We have worked with Mr. Rodriguez every year since, and our involvement in his Earth Science curriculum has increased each year.

Raquel Mendoza-Cabral–High-School Science Fair

By the time Raquel Mendoza-Cabral was in her junior year at Ramona High School (RUSD), she knew she wanted to pursue a college degree in engineering. She wanted to participate in the science fair, but her high school did not host the competition. Through GEOP's science fair mentoring program, Raquel was partnered with a UCR graduate student to design and complete a science fair project that examined the effects of rising ocean temperature on marine ecosystems. Her project "The Heat is On, Will the *Halimeda* Survive?" won the district science fair and progressed to the California State Science Fair finals, where it helped Raquel earn a scholarship to study engineering at Worchester Polytechnic Institute in Massachusetts. Because of Raquel's dedication and success, Ramona High School now hosts an annual science fair competition.

Riverside STEM Academy Capstone Project

Two high-school students at the Riverside STEM Academy (RUSD) have been mentored by UCR graduate students for 2 y (sophomore and junior year). As part of their STEM-focused curriculum, they were required to complete a year-long capstone research project. Because they had competed on the rocks and minerals Science Olympiad team for 3 y already, they chose to design a geology capstone project. Because Earth Sciences are not offered at RUSD schools, they turned to UCR for guidance. Through GEOP, they were paired with a graduate student mentor who helped them design a project that examined the geological structure and mineralogy of the Box Springs Mountains Reserve, which abuts their school campus. Their project is ongoing, and they plan to enter it in the district science fair in 2016 (when they are high-school juniors), thereby turning a capstone project into a multiyear research project. Because of this project, they have both expressed an interest in pursuing college degrees in geology.

Noah Planavsky–Graduate Student and Mentor

As a graduate student at UCR, Noah Planavsky used geochemical analysis of ancient rocks to study the rise of oxygen in Earth's early atmosphere. As a recipient of the NSF Graduate Research Fellowship, Noah was self-funded and did not have an opportunity to teach in the classroom during his graduate studies. Noah wanted to develop teaching skills, so he signed up to mentor two juniors from Martin Luther King, Jr., High School on their science fair project, "Developing a Toolkit to Track Oxygen Depletion in Past Oceans." Noah met with his students once per week through the fall quarter, and together, they created a sophisticated science fair project that progressed to the California State Science Fair. Noah's time as a mentor provided him with teaching experience and helped him learn how to communicate complex science to a high-school audience. Noah has since joined the geology and geophysics faculty at Yale University.

Noah's experiences as a mentor are typical of UCR student participants in GEOP. In a survey conducted of graduate and undergraduate participants in GEOP, 100% (19/19) reported a gain in both teaching and science communication skills, whereas 78.95% (15/19) reported a gain in understanding of issues surrounding education, and 57.89% (11/19) reported a gain in understanding of issues surrounding diversity. Participants also benefitted through experiencing gains in confidence or other intrinsic/emotional rewards (78.95%, 15/19) and through resume/curriculum vitae enhancement (68.42%, 13/19). This survey, conducted over a 1-wk period in October 2015, was disseminated to all current and previous participants in GEOP, with a response rate of 12.67% (19/150).

Community Outreach Events

In 2011 and 2012, GEOP participated in UCR's *Refresh Riverside: A Community Climate and Sustainability Fair*, which brought local middle and high-school students and their families to the UCR campus to learn about the science of climate change and the importance of living sustainably in a vulnerable region. Each year, more than 700 people attended the fair. GEOP hosted several booths with information, interactive demonstrations, and educational games designed to teach fairgoers about local and global climate change. *Refresh Riverside* was the first large community outreach event that GEOP participated in, and the materials produced for this event were evaluated via surveys (see below) and have been reused several times at other community outreach events.

Refresh Riverside fairgoers (adults and children) were surveyed about their experiences at the fair in 2011 and 2012. The survey was offered in English and Spanish, and respondents received little instruction so that they would write whatever was most salient to them on the day they responded. In both years, roughly half of adults (55% in year 1 and 46% in year 2) mentioned something related to learning, teaching, or information. Other common topics mentioned in surveys include fun, conservation, hands-on learning, and suggestions for improvement. There were 71 child responses (all in English). The children's survey consisted of three short questions: (1) something I already know about climate change, (2) something that I learned today about climate change, and (3) what I liked most about today. There were 70 responses to the question, "What I already knew about climate change," 48 of these 70 responses (69%) mentioned something directly related to climate change. Because this survey was not distributed to children before they visited the fair, it is likely that some of these responses about climate change were facts that the children learned at the fair. Of the 59 responses to the question "what I learned about climate change today," most of the children (58%) described something related to climate change or the actions that can be taken to mitigate climate change. Of the statements that were not directly related to climate change, GHGs, or global warming, six of them (10%) mentioned learning some other scientific or environmental fact.

In 2012, the City of Riverside began hosting an annual event called *The Long Night of Arts and Innovation* to display the best STEM and creative arts projects in Riverside. Local universities, colleges, and K–12 schools, as well as private design firms and technology-development companies, were all asked to participate. The event lasts from 4:00 PM to midnight and receives more than 10,000 visitors. Since its inception, GEOP has hosted several booths at *Long Nights* designed to teach the citizens of Riverside about geosciences in their daily lives. We have focused on earthquake hazards and the effects of global climate change. Visitors to *Long Nights* can talk to geoscience experts, simulate earthquakes using the Quake Catcher Network, play educational games like "The Carbon Price is Right!," and calculate their household's carbon footprint. In addition to these interactive booths, GEOP has arranged for Earth Science professors to give public lectures on earthquake hazards and global climate change.

IMPLEMENTATION

If a department wishes to establish an outreach program like GEOP, it can take simple steps to maximize the effect on a small budget. Here, we list the steps and best practices for implementing a program like GEOP at another university.

Step 1: Designate a Program Manager

The graduate student program manager of your outreach program is crucial. As described above (see "Program Design"), the program manager is responsible for coordinating day-to-day operations, scheduling presentations and events, and assigning volunteers to each event. In 6 y of GEOP, we have had four program managers; each manager served for 1–2 y.

Step 2: Evaluate Existing Resources

Every university department has a wealth of existing resources. Most Earth Science departments possess collections that can be used to construct teaching kits for a rocks and minerals or fossils presentation. Although few departments or universities have official natural history museums, many have permanent display cases in hallways. These can be incorporated into activities and presentations when school groups visit campus. Research laboratories are also excellent stops for tour groups and provide an opportunity for K–12 students to meet and chat with geoscientists.

Graduate and undergraduate students are a department outreach resource as well. They will form the basis of your outreach program's team of volunteers. At UCR, we found that a small group of dedicated volunteers (6–10 reliable graduate and undergraduate students) can easily accommodate 75–100 outreach events per year.

Finally, take account of existing STEM outreach programs at your university. Although another department's outreach program may have different goals or methods, there will likely be several opportunities to collaborate at events or on projects. Better communication among your university's various outreach programs will strengthen STEM education in your region and provide K–12 students with abundant opportunities to become engaged in STEM fields.

Step 3: Use Funding to Create Reusable Teaching Materials

Once you have evaluated your existing resources, spend a portion of your budget on durable, reusable teaching materials. For GEOP, we used U.S. $1,000 of departmental money in years 1 and 2 to build educational games and activities and to print laminated posters on important topics. These materials have been used in nearly every type of outreach event, from in-class presentations for elementary school students to large-scale community events targeted at adults. Nearly all of GEOP's reusable teaching materials are tailored for residents of Riverside. For example, our laminated climate change posters highlight the effects and projections for Riverside County. Earthquake posters highlight hazards related to the San Andreas Fault Zone. Paleontology materials highlight fossils found in Riverside County. This place-based approach gives the audience a personal connection to the material and allows them to engage more easily.

Step 4: Build and Maintain a STEM Education Network

Your program manager should be responsible for communicating directly with local schools, community leaders, and other campus-outreach programs. GEOP's greatest successes have been the result of repeated interactions with individual teachers or students year after year (such as Edgar Rodriguez's 6th-grade curriculum or the Riverside STEM Academy (RSA) students working on the Box Springs research project).

CONCLUSIONS

As the geosciences face a severe worker shortfall in the near future, we must develop new methods for engaging and recruiting new students, especially those from historically underrepresented minorities and other communities without easy access to the geosciences. Many university Earth Science departments seek to address this issue but have difficulty launching new programs. The GEOP model presented here allows departments to establish a working, effective program without a large start-up budget or grant support. The simplicity and flexibility of the program allows departments to adapt to the unique needs of their local communities. Ultimately, university departments can launch outreach programs following the GEOP model, which, then, may serve as pilot programs for large-scale and grant-funded outreach projects.

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