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In The Trenches

THE NEWS MAGAZINE OF THE NATIONAL ASSOCIATION OF GEOSCIENCE TEACHERS

Undergraduate Research in the First Two Years

IN THIS ISSUE

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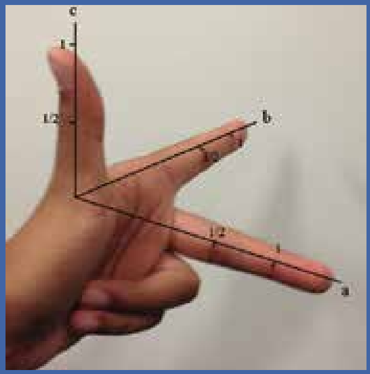

Using gesture to represent crystallographic axes. [Photo by Kinnari Atit, CC BY-NC-SA 3.0.]

In The Trenches

Editor in Chief: Cindy Shellito
Guest Editor: Kaatje Kraft
Managing Editor: Nancy Ashmore

On the Cover: Earth System Science class students at Central Wyoming College and their instructor, Suki Smaglik, sit amid fossil travertine terraces while exploring research topics at Hot Springs State Park, Thermopolis, Wyoming. (Photo by Austin Buckingham)

In the Trenches **(ISSN 2372-1936)**
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NAGT

Letter from Guest Editor Kaatje Kraft

Undergrad Research in First Two Years Can Make Huge Impact

In March I had the joy of watching my students present their research on soil and water quality to farmers from a local organic farm who support returning veterans (http://growingveterans.org). Seeing that their research had meaning and value made the students excited about all the work they had done on their projects. It is experiences like these that led me to guest edit this issue of *In the Trenches*.

Faculty members who teach at the introductory level frequently hear about the obstacles our students face to persist and be successful. It is easy to think that this may mean that standards need to be lowered in order for students to be successful or that we can not take risks that overly challenge students in the first two years—and yet undergraduate research (UGR) in the first two years proves quite the contrary. In this issue, you will learn more about why UGR in the first two years is considered a high-impact activity and see some concrete examples that range from individual student projects to whole class projects. In the table below is a basic breakdown of the key ideas for each article. I hope you'll find some inspiration for your own teaching practices.

Would you like to learn more about resources that exist around UGR in the first two years? A recent On the Cutting Edge Workshop brought together resources, sample activities, and ideas from faculty at two and four-year colleges/universities across the country. You can find the results at http://serc.carleton.edu/NAGTWorkshops/undergraduate_research/workshop_2014/index.html.

In addition, be sure to check out the Council for Undergraduate Research (http://www.cur.org). An organization dedicated to implementing UGR for all students at all levels, it has a geoscience-affiliated subdivision: http://geocur.org. Learn from others and be inspired!

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Honing a Healthy Disregard for the Impossible: Undergraduate Research in the First Two Years

Mesa Community College student Krysta Paffrath and Professor Niccole Cerveny discuss geological characteristics of material found in the field while walking between research sites in the Petrified Forest National Park, Arizona. [Photo courtesy of Niccole Cerveny]

Undergraduate research (UGR) opportunities have been identified as a high-impact practice toward student engagement, retention, completion, and education (Kuh 2008). Yet my experiences facilitating Council on Undergraduate Research (CUR) workshops to institutionalize UGR reveal that the methodology of inquiry-based learning in authentic research projects is largely underutilized with undergraduates, particularly those in their first or second year. The primary barriers for faculty to engage first- and second-year college students in undergraduate research projects center around time, resources, and institutional support (Hewlett 2009). What are freshman- or sophomore-appropriate undergraduate research projects anyway? How much do they cost in terms of time and resources? How can you gain adequate institutional support?

Considering that first- and second-year college students have most likely not been enveloped in the paradigms of geoscience thought and theory, it is appropriate to first identify the undergraduate skills that should be mastered in order to build a solid foundation for future geoscientists. Surprisingly, many of these skills are universal to all science disciplines and do not necessitate great depth of content exposure to get started. (See Figure 1). In fact, students who are exposed to hands-on research opportunities are more likely to dive into the content, as content is perceived to have more value and context (Russell, et al 2007). Additionally, students who are involved in UGR are more likely to complete their undergraduate educations. And students from departments that are strong in research and teaching demonstrate the

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highest intellectual growth (Crowe 2007).

Faculty teaching introductory-level courses, particularly lecturers at four-year colleges or universities and community college faculty, carry such high teaching loads that there isn't much time left for meaningful mentorship in research. Consequently most undergraduates do not experience UGR opportunities until they are in their third or fourth year, where their grasp of content is better and some aspects of their projects can be completed without direct faculty supervision. Yet early exposure to UGR experiences benefit students and STEM fields through the positive impacts on student retention and completion, the engagement of underrepresented students in science, and the preparedness of the geoscience workforce (Hathaway, Nagda, et al 2002). Therefore, we should engage in UGR pedagogy as soon as possible in a student's academic experience.

Students need to have opportunities to learn the culture and norms of the discipline along with the science or disciplinary content of the project. Unfortunately, many non-research-based institutions of higher learning are not equipped with cutting edge technology within the discipline. Remember that your goals for engaging students in these high impact activities are for the development of the student and not directly related to the research reputation of an institution. Considering again the list of undergraduate skills for first- and second-year students in Figure 1, what kind of equipment do you already have access to for completing a meaningful research experience with your students? Likewise, careful consideration of the supplies necessary for a high quality experience for your students require creative repurposing and surprising collaborations throughout your campus. Even though budgets are constrained and literature resources can be scarce, librarians on college campuses are eager to help both students and faculty with research resources. Finally, teaching faculty can accomplish an amazing amount of UGR

Problem Solving/Critical Thinking

- Evidence Based Thinking
- Making Inferences
- Integrating Qualitative and Quantitative Evidence

Communication

- Scientific Writing
- Interpretation of Results/Data
- Make a Professional Poster/Presentation

Collaboration

- Collaborative Problem-Based Reasoning
- Peer Review
- Team Building

Literature/Library

- Reading Scientific Literature
- Library Research
- Understanding and Using Abstracts

Technical/Technology

- How to Approach a New Piece of Equipment
- Trouble Shooting
- Statistics

Content Knowledge

- Application of Theory
- Analytical Reasoning
- Awareness of the Disciplines

Basic Professional Skills

- Organizational Skills
- Record Keeping/Research Portfolio
- Ethics

Affective Dimension

- Persistence
- Inquisitiveness/Curiosity
- Scientific Attitude

Figure 1: At a recent Council on Undergraduate Research workshop on integrating undergraduate research into the curriculum for 2YCs, faculty identified the above as research skill categories and associated example skills that better prepare students for their upper-division education. This is not a complete list, but a sampling of each category.

experiences with small, locally based grants. Larger, national-scale grants also recognize the value of early engagement of undergraduate students in research. Consequently, there are numerous grants specifically awarded toward undergraduate research proposals.

Institutional support can truly ease a professor's ability to engage students in UGR. Often, simply recognizing that faculty are actively mentoring students and acknowledging the effort is a key step for administrations to demonstrate the support for high impact practices at the college. As institutions turn their focus toward outcomes, retention, and completion, they become aware that the development of research skills also develops critical academic skills. Literature shows that students from diverse backgrounds do not identify with the academic mission of the institution and/or are not made to feel welcome in the same way that "majority" students do (Derting and Ebert-May 2010). Close contact with faculty outside the classroom, as often happens in research projects, is key to retention of diverse students. Invitation to participate in faculty research is a non-remedial approach to student retention with high expectations for student academic success. And an invitation to participate in research sends a message to students that they belong in this field or discipline. Additionally, close contact with diverse students outside the classroom provides an important education to faculty about the value of diversity and unique barriers that affect students from different backgrounds.

CONCLUSION

We can harness the powerful impact that undergraduate research has on learners in such a way that more students can experience it more often by integrating common research skills into the curriculum of first- and second-year courses. In this way, students will develop these skills at the foundational level for all fields. In a recent poll of employers, 93 percent said that a candidate's undergraduate major was less significant than a candidate's ability to communicate effectively and apply knowledge to real-world problem solving (Hart 2013). Yet the 2010 report from the National Academy of Sciences shows the United States continuing to fall behind in job creation and preparedness for a more STEM-driven global economy. It is our obligation to help the future geoscience workforce by making undergraduate research opportunities available and overcoming the habitual barriers. We must continually develop a healthy disregard for the impossible, helping students define their learning goals and assisting them in achieving them.

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Students Learn Geoscience by Researching the Perceptions of Classmates

The geoscience education research project at Community College of Rhode Island allows students to participate fully in original research, from asking a research question to collecting and interpreting data and communicating their results, without requiring specialized equipment. This article describes this novel approach to undergraduate research and presents student reflections of their experiences. Full directions, handouts, and teaching tips are posted on the SERC website (http://serc.carleton.edu/NAGTWorkshops/undergraduate_research/workshop_2014/activities/88699.html).

Because most college students take only one or two science classes, it is important that their experience meaningfully teaches them how science works. However, most students do not better understand the nature of science after taking a traditional science course (Abd-El-Khalick, 2006; Nadelson and Viskupic, 2010). The nature of science needs to be made explicit to them (Abd-El Khalick and Lederman, 2000), and a useful way to do this is for students to do scientific research and reflect on how their experience shows how science works.

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This project begins with a research question: "What do other students think about ____?" Students fill in the blank with a geoscience topic that interests them. Although this project is based on geoscience education research, faculty do not need education research expertise to run this project. Students, who are usually not science majors, also enjoy the human component to the research, as illustrated by this student's comments: "[It] allowed us to see what other people thought about our topics and not just what the Internet and books say. This allowed us to have human insight."

One advantage of this project is that students

participate in the entire scientific process from beginning to end and not just with pieces of it. Students do background research of the scientific perspective to their research question and develop methods (in this case, create a questionnaire) that help them answer their question. After collecting data using their questionnaire, they analyze it and make interpretations about their results. Finally, they discuss the implications of their findings and present their entire research project to the class.

Because many students are not familiar with the process of science, they tend to think of it as formulaic with no personal touch: "Before doing this project I thought that in order to do good quality scientific research we must follow the scientific process like a map, but in reality doing good scientific research involves more of working around problems we might encounter along the way."

Another student explained: "The research project introduced me to the idea of discussion of data. This is the most enjoyable and useful part of the scientific process, yet I was unaware of this step in the past."

Throughout the research project, I incorporate reflections on the nature of science. For example, when the scientific process of learning about the extinction of the dinosaurs and asteroids is discussed in class (Farkas et al., 2010), students relate their scientific journeys with that of Alvarez.

This project has the benefit of hooking students with a topic of personal interest. Students have explored wide-ranging topics such as what other students think about how mountains form, whether dinosaurs and humans lived together, and why geysers erupt. Because the topic is their choice, they are more invested in learning, and the results are more meaningful to them. As an illustration, one student wrote, "One of the reasons I enjoyed my project so much was because I really wanted to know the answer to my question."

I structure this project in my classes as a semester-long project capped by a presentation. However, this approach to geoscience research is flexible and can be scaled up or down. For example, I scale it up for students doing Honors projects with writing a scientific paper.

In order for students to experience giving constructive feedback as well as to lighten my workload, I have students peer-evaluate several checkpoint assignments. For example, students critique each other's questionnaires, using guidelines I provide. In this way, students get the benefit of peer review, and I get the benefit of lessening the workload for each milestone turned in. It is important to structure time for this feedback and for students to solve problems. Frequent deadlines have proven to be essential because students often do not realize the complexity of doing research—as shown by this student's comment: "There was quite a bit of a learning curve when it came to actually doing scientific research. I thought that the project as a whole would be more clean cut but it turned out to be far more complicated than I initially assumed."

The benefits of this project, and in essence, any undergraduate research is summed up by this student's reflection:

"This particular project teaches you to go out and collect data rather than sitting in front of a computer looking up info. It also helps you brainstorm and use your own creativity like a real scientist. When doing this, you are learning … and using your own knowledge to put things together rather than just using info another scientist already put together."

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Building Success into a First-Semester Undergraduate Research Course

One could think of reasons why engaging *first-semester* undergraduate students in research is difficult. Students lack content knowledge and research skills, can be intimidated by the research process, and might not even recognize that doing research is a valuable activity. On the other hand, benefits of early student research experiences are well documented: 1) there are direct benefits to students (Lopatto 2004), 2) authentic inquiry is an effective pedagogy in science education (Singer et al. 2012), and 3) early research experiences can attract or retain students in STEM disciplines (Lopatto 2007; Taraban 2008). The challenge of creating an early undergraduate research course is to overcome the

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FYRES Mentor (left) stands back while first-year students implement their research design to investigate effectiveness of sand fences on a steep dune slope. (Photo by Deanna van Dijk)

difficulties in order to realize the benefits.

From 2011 to 2014, the First-Year Research in Earth Sciences (FYRES) project has engaged 81 first-semester Calvin College students in research on Lake Michigan coastal dunes. The research experiences are substantive, as demonstrated by first-year student coauthors on 18 conference presentations and 17 research reports. Other measures of success are also important, such as high student satisfaction levels and increased numbers of students continuing in STEM fields.

How does the FYRES project create a successful first-semester undergraduate research experience? Many real challenges have been met by building a variety of support structures into the FYRES course.

Student success begins with attracting suitable students to the experience. “Suitable” is not defined by content knowledge (no prior knowledge is assumed) or disciplinary interest (both science and non-science students are welcome) but in terms of a basic level of interest and motivation for participating in a non-traditional science course. An online application process ensures that students have at least enough motivation to complete the application. Recruiting materials avoid specialized terms such as “geology” or “geography” which are unknown disciplines to many high school students. Course credit fulfilling a general education physical science requirement provides a recognizable value to participation for non-science students. Science-oriented students are attracted to the early opportunity to gain disciplinary experience and help with vocational decisions. Most students are attracted by the promise of hands-on learning and an atypical setting: the Lake Michigan coastal dunes.

Because no prior content knowledge or research skills are required for student participation, the course structure uses the five-hour lab periods, three class periods per week and assignments early in the semester to build the foundation for the substantial research project in the last half of the semester. The pre-research-project lab activities introduce students to different dune environments, methods, equipment, and data analysis. Dune content knowledge is built during classes that often refer to what students have experienced at the dunes. A short paper assignment has students finding and reading reputable sources about dune topics and practicing a scientific style of writing.

Three first-year students implement their research design to investigate characteristics of planted vegetation. FYRES Mentor in background is focusing on her own field notes but is close enough to answer questions as needed. (Photo by Deanna van Dijk)

A well-scaffolded process for the principal research project enables students to construct the content of their experience within a supportive framework of clear guidelines. Research is done in teams of first-year students with leadership from upper-level students (FYRES Research Mentors) and the faculty instructor. Authentic and meaningful research topics are provided to the research teams after consideration first by faculty (for topic suitability) and then by Mentors (for background understanding). To foster a sense of topic ownership, research teams are constructed based on preferences indicated by students. An annotated bibliography assignment builds student content knowledge (see resource list). Each research team is guided through a research design process to plan appropriate methods of data collection and analysis. Student teams implement their research designs over three weeks. Course requirements that teams will communicate their results lend weight to the authenticity and value of the research. Students are provided with assignment guidelines, two lab periods, and mentoring towards creating a conference-style poster and oral presentation. At the end of the semester, the student research teams give their oral presentations and present their posters at a campus-wide poster fair. Both audiences include people outside of the class, such as other college faculty and students, community members, and dune managers.

Utilizing FYRES Research Mentors meets two challenges of providing effective research experiences for a class of 24 first-year students. The Mentors make the field research and teaching logistically possible by driving vehicles and working with small groups of students at different sites. The Mentors also reduce the intimidation that first-year students may feel if asked to lead the research effort (Caristi and Gillman 2002). (The students may not realize that they are given increasing responsibility for making research decisions as the semester progresses.) A Mentor-student ratio of 1:4 (6 Mentors, 24 students) has worked effectively for the early-semester labs as well as the research teams. The Mentors are supported in their work by a two-day training session prior to the semester, guides to upcoming activities provided in advance, weekly one-hour group meetings, and individual mentoring from faculty as needed.

Because the semester length and student inexperience make it too difficult to include a written report, the FYRES Mentors continue the project work into the following semester. Typically, Mentors do additional reading and data analysis to ensure the research is complete. Mentors also prepare a research presentation for a regional conference. The first-year students are invited to attend the conference (actual participation varies by year) and each student receives a printed copy of the final research report.

The support structures built into the FYRES course are effective for enabling first-semester undergraduate students to complete a substantive geoscience research experience. Weekly journal entries and an exit questionnaire show student awareness of how much has been accomplished and what it means to *be* a geoscientist for a short time. Comments from students include “This course turned out to be the best class I took this semester. Initially I thought that I would not ‘fit in’ or be as enthusiastic as other students with environmental studies or science as their majors, but I’m pleased to say that I thoroughly enjoyed the class” and “I’m leaving this class feeling like I could see myself working somewhere in this field.”

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GETTING INTO HOT WATER

High-Impact Projects Provide Early Undergraduate Students With High-Level STEM Skills

Left: Central Wyoming College students sample hot springs water and microbes for class project at Hot Springs State Park in Thermopolis, Wyoming. (Photo by Lance Murakami)

In little more than a decade, the undergraduate research program at Central Wyoming College (CWC) has grown from one student, one instructor, to five instructors and five to ten students each year. Maintaining a culture of undergraduate research has become an objective in our institutional strategic plan. Because I had the opportunity to do undergraduate research in my early years, I knew the importance of this type of experience for my students. CWC is a low-income, at-risk, minority-serving institution, which means most of our students only see scientists on TV and have a hard time seeing themselves in that profession. I wanted to empower our students with the opportunity to work on a research project. With financial support from small ($5K-$25K) grants through the Wyoming Space Grant Consortium (WSGC), Wyoming Experimental Program to Stimulate Competitive Research (EPSCoR/NSF), Wyoming Institutional Development Awards (IDeA) Network of Biomedical Research Excellence (INBRE /NIH) and the Community College Research Initiative (CCURI/NSF), we have been able to support our students as research interns, taking them to present their work at conferences, both local and national. Participation in research projects has huge impacts on 2YC students, who go on into the STEM pipeline with skills and knowledge that their four-year counterparts may lack.

While I have several disparate research projects ongoing, this article focuses on the thermophile habitat and genetic diversity of a local hot spring. As a lone ranger at CWC, I knew that I would have to reach out to other geoscientists in order to gain anything close to the community that exists at larger four-year/graduate institutions. I took any opportunity I could to learn as much about my new "neighborhood" as possible. The thermophile project began after I was introduced to microbial research in nearby Yellowstone National Park during a Chautauqua field course.

I had been trained as a hard-rock geochemist, and microbial ecology was far from my expertise. Curiosity and a willing student led to applying for funding from the WSGC for a reconnaissance mission to Thermopolis. And into the fray we went. Our first project was to map out the nature of the mats and their relation to the hot water source. Mapping. I can do that. Water chemistry. Check. Now we're onto something. We even threw in a bit of microbiology and tried to extract DNA from these little buggers. There's a reason that they survive under extreme conditions!

Six months later we still didn't have anything. It wasn't until this student became the first INBRE transfer-scholar at the university, receiving full tuition for two years to complete his BS and a rotation through graduate-level research labs, that we learned how to extract DNA from extremophiles. Without this "backward" collaboration, we would have moved forward at a much slower pace. One of the ongoing benefits of research is to tap into a growing network of expertise from which my students and I can both learn.

A few years ago, CWC became part of the CCURI. They have provided much needed equipment, funding for genetic sequencing, and travel to conferences and training workshops. CCURI's mission is to bring authentic research experiences into the biology (or other STEM) classroom. With their help, we have been able to take this research beyond the simple questions. We've since added units in bioinformatics and geophysical methods to the project.

We now use this research as a project in our sophomore-level geology course on Earth systems. In lieu of a final exam, all students (whether as small teams or individuals) are required to present their research at the Wyoming Undergraduate Research Day held at the University of Wyoming (UW). The UW students present senior theses and engineering capstones; our freshman and sophomores present graduate-quality work. Some of us have taken these same students to present their work at national conferences. In other words, our students have a better opportunity, earlier, with us, than if they had gone straight to the university.

These research opportunities are powerful

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experiences for students and faculty. Lessons learned over the years include:

1) You never know where ideas will come from, always be ready to think about how something could be twisted into a possible research experience for your students.
2) Keeping it local helps with logistics.
3) Standards don't need to be lowered, but learning experiences need to be well scaffolded so that they can get to that high level of expertise.
4) Publications may not always be the final result, but going public is still an important part of the learning experience.
5) By creating an undergraduate research culture on campus, you can make a difference for many students.

RESOURCES

For more information about this activity and about thermophilic microorganisms, visit:

http://serc.carleton.edu/NAGTWorkshops/undergraduate_research/workshop_2014/activities/87130.html

http://serc.carleton.edu/microbelife/index.html

Nominations Due by June 15 for NAGT Outstanding Teaching Assistant Awards

NAGT recognizes outstanding teaching assistants in geoscience education with up to 30 awards annually. Both undergraduate and graduate teaching assistants are eligible for the award. Nominations are due June 15, 2015.

Award winners receive a one-year membership in NAGT, which includes an online subscription to the *Journal of Geoscience Education* and *In The Trenches* quarterly magazine.

For more information and a link to the online nomination form, visit: http://nagt.org/nagt/students/ta.html

New Online Workbook Offers Spatial Thinking Exercises

Spatial thinking is essential in the geosciences. While undergraduates display a wide range of spatial thinking skills, research shows that these skills can be taught. A team of geoscientists and cognitive scientists has developed instructional activities designed to do just that.

The penetrative thinking exercises in the Spatial Thinking Workbook (http://serc.carleton.edu/spatialworkbook/index.html) require students to visualize slices through a variety of objects, both geological and non-geological. Ranging from simple to complex, the exercises use instructional strategies informed by cognitive science research and tested in mineralogy, sedimentology and stratigraphy, and structural geology courses at three different institutions. For more information and to view a selection of the exercises, visit the project website.

Contributors to the project include: Carol Ormand, SERC, Carleton College; Thomas F. Shipley, Temple University; Barbara Dutrow, Louisiana State University; Laurel Goodwin, University of Wisconsin-Madison; Thomas Hickson, University of St. Thomas; Basil Tikoff, University of Wisconsin-Madison; Kinnari Atit, Johns Hopkins University; Kristin Michod Gagnier, Johns Hopkins University; and Ilyse Resnick, University of Delaware.

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MY FAVORITE DEMONSTRATION

Do you have a favorite demonstration that helps students understand an aspect of Earth or space science? Feel free to submit your idea (whether it's a few sentences or a longer article). Use the URL noted above to contact us.

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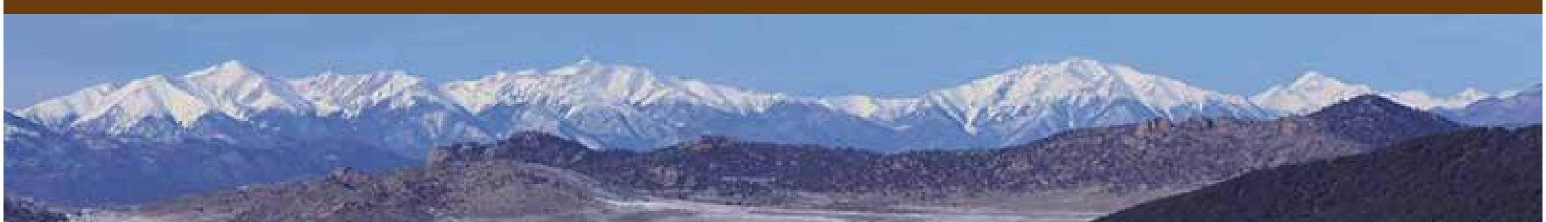

Earth Educators' Rendezvous 2015
July 13-17 | University of Colorado, Boulder

REGISTER TODAY! The first annual Earth Educators' Rendezvous welcomes undergraduate faculty from all disciplines who are interested in improving their teaching about the Earth, administrators from geoscience departments and interdisciplinary programs that want to become stronger, and education researchers of all types. For further information, see page 13. See you in Boulder!

To register, visit https://serc.carleton.edu/earth_rendezvous/2015/registration/index.html