Science Communication Development

Peter Anderson, University of Houston

Public science education in the United States faces many hardships, ranging from teachers that are assigned classes they are not experts in, to the wholesale distribution of categorically wrong information being taught form a position of authority as scientific and historical fact. Through direct interaction between scientists and children, both still enthusiastic and striving to teach and learn respectively, we can create an atmosphere of intellectual curiosity that facilitates both interest and inclusivity. An informal and reoccurring program in which the local community is engaged directly by academics facilitates this goal. The experts best equipped to foster scientific inquiry are trained scientists, and enthusiasm to participate is growing, Increased enthusiasm is, in part, a response to external forces (NSF) requiring the inclusion of the, "broader impacts," category in funding proposals.

Our research shows a much greater level of support, enthusiasm, and importance placed upon this in the current and upcoming generations of academics (our present graduate, undergraduate and post-doctoral students). This trend seems to emerge repeatedly throughout the scientific community, and is one we hope is emblematic of the new generation of academics. Many of the participating presenters, students and teachers, feel a civic responsibility to be involved in programs that allow primary school children to interact with, "real scientists," directly. Several of student participants report positive experiences, stating explicitly that this program has aided in their professional development as teachers, and communicators of complex scientific material to audiences of variable content knowledge levels.

Using NSF TUES 1 and TUES 2 to Develop and Disseminate Best Practices.

Mary Beck, Valencia College

I am a fulltime 2-year college faculty and a PhD student in geoscience education. As part of my early graduate experience, I participated in a TUES 1 grant that looked at integrating undergraduate research activities into an undergraduate petrology course. This project was my first collaboration between my 2YR college and my PhD university. I then received my own TUES 1 grant implementing my own plan for integrating undergraduate research and inquiry activities into my physical geology and new summer geology field courses. I am now part of a TUES 2 grant looking at extending the best practices developed in the TUES 1 grant that I participated in as a graduate student. The TUES 2 grant involves collaboration between my 2YR college, my PhD institution, and 2 other universities. The NSF model for piloting and extending best practices in education is one model that provides structure and support for across-institutions collaboration. I would like to see a network that can partner interested parties in setting up similar types of collaborations between institutions. SERC provides a number of collaborative initiatives and may be a good choice for housing a GER collaboration network. The NSF tiered model may be useful in terms of providing information on smaller projects that may be scaleable and for providing a means of connecting collaborators. This may also be a way to connect "experts" in different areas of GER.

Future GER (Research) Should be Directed by Results of Meta-Analysis of Fragmented Literature on Active Learning Interventions

Scott Brande, University of Alabama at Birmingham

I think the most important (and recent) paper published in the field of STEM learning is that by Freeman et al (2014) Active learning increases student performance in science, engineering, and mathematics http://www.pnas.org/content/111/23/8410.long. After filtering 642 research literature reports on traditional and active learning, 225 studies passed a number of requirements for inclusion in this massive meta-analysis. No surprise that the bottom line is that active learning interventions (taken as a whole) significantly reduce course failure rates, and raise grades by about ½ a letter.

The figures and supplementary tables are worth studying, for the data are broken down by STEM discipline. In Fig. 2 for example, of 158 studies, the geologic literature contributed the least - precisely 2 (thanks for your work, Dave McConnell and co-authors, 2005, 2006). McConnell's studies resulted in a decreased failure rate of about 8% (from the figure) - the lowest impact of 53 studies among 7 STEM disciplines.

Wieman (2014) http://www.pnas.org/content/111/23/8319 commented on the Freeman et al study, and he noted that the "...implications of these meta-analysis results for instruction are profound, assuming they are indicative of what could be obtained if active learning methods replaced the lecture instruction that dominates US postsecondary STEM instruction. With a total annual enrollment in STEM courses of several million, a reduction in average failure rate from 34% to 22% would mean that an enormous number of students who are now failing STEM courses would instead be successfully completing them. The expected gains in learning for all students in STEM courses are equally important."

What may be most relevant for the GER community is the direction Wieman believes educational research should take. 1) Further research should identify "...the relative benefits of different active learning methods and the most effective means of implementation." 2) "...One promising direction ... is that 'more is better'. The highest impacts are observed in studies where a larger fraction of the class time was devoted to active learning."

For our community, this means that traditional lecture minutes should be reduced, with the concomitant increase in minutes devoted to the most promising active learning interventions.

I believe the Freeman et al study, and Wieman's comments, provide the general direction we should follow, with the details a topic for our domain-specific discussions.

"When you come to a fork in the road, take it."

Caitlin Callahan, Grand Valley State University

I started my graduate studies in geology with the idea that I would ultimately transition into geoscience education after I earned a PhD in a sub-discipline. I was originally introduced to science education as a field of study through my position as an assistant in the Education Department at the American Geosciences Institute, where I worked for three years after college. As part of my duties there, I assisted with a workshop for K-12 curriculum developers from all STEM disciplines. One of the presenters at the meeting was from the AAAS; she mentioned that the AAAS was then offering funding for post-doctoral research positions in science education. The expectation was that candidates would have a PhD in one of the STEM fields but would be interested to transition to the study of learning in the discipline. That PowerPoint slide planted a seed in my mind: I could pursue a PhD in Geoscience and then transition into Geoscience Education.

After AGI, I began to pursue that path. I earned a Masters in Geology. Then I moved on to a PhD program. But multiple problems developed. After three years, I made the difficult decision that I could no longer stay; however, I was not prepared to abandon my academic goals entirely. I started to search for PhD programs in Geoscience Education. I approached the task similar to how I had originally approached searching for graduate programs in geology. I read papers. I found an article in the Journal of Geoscience Education entitled "Research in Science Education: The Expert-Novice Continuum" by Dr. Heather Petcovic and Dr. Julie Libarkin. I was captivated. I had grown up thinking that expertise was mostly about intelligence. The article conveyed that expertise is much more interesting and complex than that. In addition, the article was a powerful example of what was possible in Geoscience Education. My earlier daydreams had been amorphous. I had aspired to Geoscience Education without a concrete topic of interest. The article was a revelation; I now had a starting point. I wanted to gain a better understanding of the nature of geoscience expertise.

I applied and was accepted to the PhD program in Science Education at Western Michigan University to work with with Heather Petcovic. I was going to be a graduate assistant on a research study related to geologic expertise. I was delighted. But I also made a conscious decision regarding my future. I would be starting all over; no credits would transfer. It would mean four more years, at least, of graduate school. Even before friends, family, or professors at my former institution could voice concerns, I promised myself that I would go through with this change without having a clear sense of what my job opportunities would be after I finished. Ever since my time at AGI, I had been aware that the Geoscience Education community had been expanding and developing. I decided that I would begin the PhD at WMU without knowing exactly where it would lead. I would find a way to make a place for myself.

An Alternate Path into GER

Kim Cheek, University of North Florida

My trajectory in GER is different from many others in our community. Like many children I had a rock collection as a child, but I learned very little geoscience in school, with the exception of one Earth science course in eighth grade. My high school didn't offer Earth science, and neither did the small college where I did my undergraduate work. During my eleven plus years teaching students in grades 3-8, I was a classroom teacher and also taught special education. I always loved mathematics, so I expected to enjoy teaching it. What surprised me was how much I enjoyed teaching science. When I was offered a middle school science position, I jumped at the chance. Our geoscience unit was my favorite, which led me to earn a second masters' degree in geoscience (first one in elementary education). I loved teaching middle school science, but I decided I could ultimately impact more K-8 students, by teaching their teachers. When I entered a Ph.D. program in science education, it seemed natural that I would do my doctoral research on geoscience conceptions.

An experience I had while I was a Ph.D. student strongly influenced my decision to make GER my primary identification. I gave my first research talk at a conference in Ontario, Canada, where there were a number of GERers. I recall being incredibly nervous as a number of people in the audience were ones I considered "giants" and whose work I admired. One of those "giants" in the field, whom I had never met, invited me to eat lunch with the GER group after our session. More significantly, several of them were very encouraging to me as a new researcher. Their simple kindness enabled me to view myself as someone who could become part of the GER community.

People, like me, who come into GER from a K-8 teaching background, need to figure out how to network and develop connections within our broader community, precisely because we didn't follow a more typical GER path, and we tend to reside in colleges of education. The first piece of advice I would give a younger me would be to put yourself out there. Collaborations develop out of relationships. That means reaching out to others at and between conferences. Don't worry so much about how you think others perceive you. Second, carve out a research niche for yourself but don't feel like you are stuck on a particular path. Allow your thinking and research to evolve. Finally, keep yourself grounded in the real world of classroom practice, whether it's K-12, higher education, or both. Ultimately, our aim must be to improve the quality of geoscience education at all levels.

I believe we should encourage more people with extensive K-8 teaching experience to become part of the GER community. We need to take a more longitudinal view regarding GER. People with strong roots at various levels of the educational system enable us to carry out research that will help teachers across K-20 contexts improve classroom practice in geoscience education.

Learning the ropes in GER through multi-institution research

Christine Clark, Eastern Michigan University

Though I have conducted research in GER on and off throughout my career, it has only recently become a more focused aspect of my research. Through a department colleague, I have become involved in a multi-institution GER project that began in March of this year. So far, we seem to have been working well as a group, and there are likely several factors that are directly influencing that. First, we regularly schedule online meetings (Adobe Connect, Google Hangouts, etc.) to discuss progress. Second, we are all willing to take on tasks when they fall within our expertise, but also feel comfortable in telling each other when we cannot do something or need help with a task. Third, we all have found an aspect of our project that is our own focus, allowing each of us an area within the project to take the lead.

I think the largest hurdle for collaboration across institutions is finding people interested in collaborating with you! I was fortunate that we hired a new faculty member that was interested in working with me, and brought me in on her project. If I was working on my own, it would have been much more difficult to find people to collaborate with.

Another significant issue for me is that while I am a full professor, and have published and have contacts within my core discipline, as I spend more time teaching, I have become more interested in GER. As true for any field, beginning research in a new area can be intimidating for a number of reasons, including not knowing what the current research is, who the active researchers are, and learning the terminology associated with the field. While mentoring is often available for young researchers, I could see having mentoring available to new researchers, regardless of where they are in their career.

Finally, multi-institution collaboration is dependent on online meeting software. My university provides for us to use Adobe Connect, but not all institutions provide a similar option. One possible item that could be provided by the GER community would be an online meeting venue available for GER researchers.

My non-linear path to a GER career

Scott Clark, University of Wisconsin Eau Claire

My path to Geoscience Education Research was rather circuitous. While pursuing my PhD in isotope geochemistry, I was fortunate to spend a year as a NSF GK-12 fellow. The GK-12 program at my university was multidisciplinary, and I am sure that a key factor in the selection committee's decision to bring me on was that I had previous experience working with K-12 students when I had served as a Peace Corps Volunteer. As a GK-12 fellow, I worked with a 5th grade teacher and his class. I was fascinated to see that the range of those students' performances and efforts was strikingly similarly to what I had seen in students enrolled in college-level geology labs as a T.A. While that experience is what got me interested in pursuing this field as a career, I did not have a clear idea about how to take the next step to get into GER. So, at the next GSA meeting, I simply approached people who had GER research posters and asked for their advice on how to get into the field. Their advice led me to meet the person who would become my postdoc advisor. But before I was offered the postdoc, the selection committee had reservations based on my lack of prior GER experience. As it turns out, without having the GK-12 fellowship, I would not have been offered the position. My time as a postdoc was exactly what it needed to be. I was mentored on what I needed to do to succeed, I had the opportunities to read relevant books and articles, and I had many opportunities to collaborate with professors, postdocs, and graduate students who were approaching DBER topics from a variety of STEM fields.

My advice to my younger self would be to read, read, read, and to learn as much about statistics as you can.

Earth Science Teacher to Geoscience Researcher

Daniel Dickerson, East Carolina University

My career path began when family members gave me cool looking rocks when I was a child and my parents allowed me to play in the small ditch behind my house where I would occasionally find a frog or weird looking bug. Those informal science learning experiences helped develop an interest that resulted in part in me taking elective science classes in high school and attending the North Carolina Governor's School in the area of science. I enjoyed learning about science and made very good grades in high school. I received a small scholarship from the Colorado School of Mines, however, as a first generation college student I did not have money for the remaining tuition. I was fortunate enough though to receive a North Carolina Teaching Fellows Scholarship, which provided a full support at UNC-Chapel Hill. Due to my interest in science I majored in science education with a minor in Geology. The program was changing at that time and so, in addition to my science education degree requirements, I took all the coursework for an undergraduate geology degree with the exception of an elective and field camp. I worked full time, took classes, and got married during my four years and managed to graduate (i.e. low GPS). During that time I concluded I had small holes in many of my mental models across all scientific disciplines, which I felt uneasy about, but I had a degree. That degree was leveraged into an earth science high school teaching job where I taught earth science and created new courses in geology. That lasted two years. By that time I realized they were not small holes, but giant chasms. Strangely, however, the chasms in my scientific knowledge were not as disturbing to me as the equally large chasms I had in my understanding of the teaching and learning process, particularly related to certain content like groundwater. I was accepted into a science education graduate program at North Carolina State University where half of my coursework was in geoscience and half in education. During this time, I worked on a 3-year, NSF-funded earth science education project that paid for my MS and PhD. The education coursework and NSF research experience was invaluable. I learned a lot about reformed-based educational theory, diverse geoscience content, teacher professional development, and education research methods. Since then, I've received tenure, won some awards, taught a bunch of courses and students, published a bit, been PI, Co-PI, Evaluator, or Senior Personnel on multiple federal, state, and foundation funded efforts, and have a healthy consulting business. One of the most important things I've experienced over that time is that collaborative efforts almost always result in a superior product. I've long since stopped defining my role as the "educator" or as the "content expert" and instead have been engaged in building teams to tackle specific tasks or achieve specific goals. I try to work with genuinely nice people who are truly interested in partnerships being two-way streets. I try to be a career-builder for my colleagues but have increasingly been more particularly in focusing my efforts on those who are willing to do the same for others. Based on what I have experienced to this point, I would want my younger self to spend a greater percentage of my resources on those who deeply believe in the win-win concept. And probably most importantly, don't stress so much. I would tell myself that it's possible to achieve some measure of professional success regardless of where you start financially, what your undergraduate GPA is, or whether or not this or that grant gets funded. If I work to surround myself with genuinely nice colleagues and treat them as well as I possibly can personally and professionally, then I'll achieve professional joy.

Translating GER Results into Practice in a Large Geoscience Department

Kathy Ellins, University of Texas at Austin

I have implemented the published results of geoscience education research into three different courses at The University of Texas at Austin (UT Austin). Of these, two courses were specifically designed for pre-service teachers. One course was piloted as part of an NSF-sponsored research project with an evaluation component. The second course was an extension to an active NSF project, which included secondary science curriculum development, teacher professional development, research on student attainment, and project evaluation. Both courses meet the needs of science majors pursuing secondary teaching certification through the University's UTeach program for whom two geoscience courses are required. Student feedback, evaluation findings and instructor experience will inform course revision this year with the expectation that tenured or tenure-track faculty will teach the courses in the future. UT Austin adjusted class schedules and made available the necessary teaching space to accommodate collaborative, hands-on teaching and learning. Going forward, it will be important to communicate the results of the pilot runs and the value of the instructional approach with the faculty in a way that encourages course adoption. Three challenges are anticipated: (1) Identifying faculty who are open to implementing new strategies and materials in a course designed with pre-service teachers in mind; (2) providing the necessary institutional support to faculty teaching the courses in order to sustain changes in practice; and (3) ensuring that their teaching is acknowledged and rewarded.

A third course that examined the impact that connections between the arts and geoscience have on scientific investigation and public engagement was also piloted with upper level undergraduates at UT-Austin. Three instructors—a geoscience educator, geophysicist who is a tenured professor and an artist—taught the course, using a project-based approach. Students worked in groups on three related challenges in a lab setting that encouraged discussion and active learning. The team teaching approach involving instructors from different disciplines was initially challenging but ultimately rewarding and a key factor responsible for successful course implementation. Because one member of the teaching team is a tenured professor, course adoption is expected to be straightforward.

Students initially experienced varying levels of discomfort adjusting to the different class formats, instructional style, and project-based learning activities. However, student evaluations were favorable and the students performed well.

Spreading evidence-based practices through paired teaching

Sara Harris, University of British Columbia

At our research-intensive university, some new faculty members arrive enthusiastic about teaching. Even the keen ones, however, come with little training nor awareness about evidence-based teaching practices, let alone those specific to geoscience. To address the challenge of making research-based teaching more widespread in our geoscience department, we are experimenting with "paired-teaching".

In paired-teaching, a new instructor collaborates with a prior instructor in teaching an existing course that already incorporates research-based pedagogy. The new instructor experiences teaching using evidence-based pedagogies in a course where alignment of learning goals, activities, and assessments is already in place and is expected. They may design some new activities and assessments, but are not immediately responsible for the full course structure and materials. The idea is that learning to teach is just like learning other skills: you have to do it deliberately, make mistakes, reflect, and try again.

One advantage of the paired-teaching model is that the new instructor has support and feedback during this learning process. Another is that the prior instructor has an inquisitive and curious colleague asking about all aspects of the course. The ongoing conversation about pedagogical choices makes the prior instructor reflect on their own teaching practices–where are they clearly evidence-based, or not? A deliberate reflective piece facilitated by a 3rd party can help catalyze progress for both instructors. If informal faculty interactions are important for dissemination of teaching practices (e.g. Dancy et al., 2016), these semi-formal and frequent interactions in paired-teaching may be at least as effective.

Challenges in implementing paired-teaching include: buy-in from prospective faculty participants, made easier if they are brand new; buy-in from administrators in charge of teaching assignments and budget, since assigning two people to one class means there's likely a short-term hole somewhere else. However, if there are long-term benefits to a faculty member's career, both in their teaching effectiveness and time for research that they might otherwise have spent struggling with their teaching, then the upfront costs are minor.

Using this approach specifically in geoscience could be facilitated by the GER community with development of two particular items that emerged from the 2016 GER community survey:

- A database of published surveys and instruments for GER
    - If the prior instructor knew about these and implemented validated assessment instruments regularly, this would be an excellent way to introduce new faculty to the idea of collecting evidence about their own students' learning early in their teaching career.
- An annotated bibliography of "best practice" papers in GER.
    - In addition to (or instead of) annotations, if each best practice paper could be turned into a 2-page practical guide to implementation, with the key supporting data, that might be about the right length for people who are not going to read the full papers.

Widespread adoption of GER results by practitioners is likely to be slow. By implementing systematic teaching experiences, like paired-teaching, for new geoscience faculty (or pre-faculty), we may be able to speed the transition.

Dancy, M., C. Henderson, & C. Turpen, 2016. How faculty learn about and implement research-based instructional strategies: The case of Peer Instruction. Physical Review Physics Education Research, 12, 010110.

Argumentation in the geosciences

Lauren Holder, Texas A&M University

Student argumentation has been shown to be an effective way to reinforce concepts and motivate learning. We have been working with introductory students in an effort to enhance argumentation skills during problem solving by using previous research with the Toulmin model. We had a few problems with students that did not want to use the modified argumentation model, and some students suggested that even though they used the model they weren't sure if they enjoyed the structure. Luckily there was literature to suggest modifications of the Toulmin model, but even so there was relatively little literature on this topic from the discipline, as opposed to other disciplines, to support our design. I suggest that we continue to publish teaching design, but also provide robust evidence to support how and why the design impacted student learning.

Measuring students' environmental attitudes across 61+ institutions

Kim Kastens, Lamont Dougherty Earth Observatory

As an external evaluator for the InTeGrate project, I developed a survey to be administered pre- and post-instruction to probe students' interest in a career related to the Earth/environment and their motivation to tackle grand challenges related to environmental sustainability. This instrument has been deployed at colleges and universities across the country where InTeGrate courses and modules have been tested or used.

To accomplish this has required a high degree of technical and logistical support, which has come from InTeGrate's headquarters at the Science Education Resource Center (SERC). Specifically, this effort required:

- putting the survey online from my Word text, one pre-instruction version and one post-instruction;
- providing consulting services to help the instructors understand and comply with the IRB requirements of their institutions;
- providing a way to anonymize the students' responses in such a way that analysts could not see who was who but that pre- and post-responses could be matched-up (also responses from the same student in subsequent semesters);
- capturing the data as students fill out the online survey;
- keeping track of informed consent status and not releasing data for analysis until informed consent documentation for that enactment and/or that student has been obtained;
- matching up the pre- and post-instruction responses from each student
- providing a web tool to overview the status of in-progress, scheduled, and completed enactments, including how many surveys had been received from each enactment;
- combining student responses with metadata provided by the instructor and the project, such as name of course, institution, institution type.
- providing a mechanism to download data into a form suitable for analysis.

For individual PI's or projects to set up such an apparatus for a single project would be tremendously burdensome, inefficient, and seriously non-cost-effective. The GER community (or perhaps the broader DBER community) would benefit if a central organization were to provide this set of capacities as a turn-key service, for a fee. Ideally this would be coupled with providing a data archive that would safeguard and provide ongoing access to the data after the funding for the project that collected the data had concluded.

The Role of the GER Division in Promoting a Community of Practice

President Nicole LaDue, Northern Illinois University; Vice President Todd Ellis, Western Michigan University; Treasurer Kim Cheek, University of North Florida; Secretary Katherine Ryker, Eastern Michigan University

The Geoscience Education Research (GER) division of the NAGT was established to help create a community of practice for GER (Lukes et al., 2015). Responses (91) to a survey we conducted in Fall 2014 helped division leaders identify ways in which the division can support the development of a community of practice for GER. "Opportunities to network with other GERs" was identified as an important perceived need within our community. In the first two years of the division, we have created a listserv that has grown to 296 members, established a monthly newsletter, and created article, opportunity, and "Researcher in the Spotlight" features within that newsletter. Articles showcase findings and methodologies that are of potential interest to the GER community. "Spotlights" highlight the career and research of a professional in the field, and ask that person to share GER articles that have impacted their research. The GER Division meeting at GSA 2015 provided an opportunity for community members to discuss their research interests with others one-on-one during a speed dating type activity.

The GER Division has facilitated several professional development opportunities. The Executive Committee chaired a very successful session on GER Methods at the 2015 Annual Fall Meeting of GSA. Presenters were asked to share their presentations on the GER division website (http://nagt.org/nagt/divisions/geoed/methods) to provide an archive that researchers can use as needed. In March 2016, the GER division supported an AGI/AGU Heads and Chairs webinar (http://www.americangeosciences.org/workforce/webinars/benefits-and-challenges-having-geoscience-education-research-faculty-your) to highlight how geoscience department leaders can facilitate the professional success of GER faculty. In 2016, we will host a GSA session focused on methodological decision making within quantitative, qualitative and mixed methods research. While these steps addressed the initial demand from our members, it is clear that additional forums are needed to develop professional development resources for our community.

Based on the division survey and more recent community needs survey, the GER Executive Committee members have identified several short and long-term goals for the Division as it works to support the scholarly growth of its members at all stages of their career. Of particular emphasis at this time is providing support to the geoscience community for adopting effective practices to support tenure and promotion for GER faculty. Other goals include: providing professional development on quantitative and qualitative methods, virtually or face-to-face; making members aware of a broader range of options for publishing their research; providing support in tenure and promotion, possibly through the development of a list of potential external reviewers for GER; advocating for high quality GER, while not promoting any specific approach; and raising the profile of GER within the broader research community.

The Division's aim is to be inclusive. We applaud efforts to create repositories of shared materials, such as examples of high quality GER papers and surveys or instruments, and see these as ways to enable us to become a true community of practice. We are persuaded that this process needs to be as broad as possible. We are a relatively small, but growing community, and we want to encourage a range of viewpoints and research conducted from a variety of theoretical frameworks. We want to be careful that decisions about what to include are made by a spectrum of researchers who represent different viewpoints, recognizing that research that is at the cutting edge can be transformative and that many principles we all embrace were once considered on the fringe by mainstream geoscientists.

GER at a teaching-focused univeristy

Heather Lehto, Angelo State University

My career in GER started when I was working on my Ph.D. I met Len Vacher who was a faculty member at my university working in GER. Through conversations with him and listening to students talk about the modules he was assessing for the Spreadsheets Across the Curriculum program I realized I was very interested in this type of research. I decided to split my Ph.D. research into two different topics: volcano seismology and GER. I had no idea where to start, but I had an idea I wanted to test. I found it incredibly difficult to find papers in science education research because there were too many different sources and subtopics. The amount of material was overwhelming. I started with the Journal of Geoscience Education and then branched out to other science ed journals and did finally get a good study put together. However, I still feel as though I am missing a lot of the seminal papers and so I have slowly been creating a growing list by talking to peers at GER events and through the SERC website.

I have also found it difficult to wear two hats in my research. All of my research since starting at my university has been in geophysics and not in GER. This has mostly bee because I have only undergraduate student researchers and they generally want to do more traditional research projects and because of the heavy 4/4 teaching load that I have. I have found a new and important topic that needs to be addressed at my institution and others; however, this study will require a qualitative method which I am unfamiliar with. I began taking short courses on qualitative methods at the Earth Educators Rendezvous last year and will be using this year's event to find collaborators with experience in qualitative methods and in cognitive science.

The most difficult part for me has been finding the time to plan and run studies as well as finding primary literature and collaborators. This has been helped immensely by the strong push towards building a GER community and the Earth Educators Rendezvous specifically. My advice to my younger self would be to keep finding new opportunities and to learn to clone myself.

Cultivate Partnerships to Build Your GER Career

Sharon Locke, Southern Illinois University Edwardsville

My interest in geoscience education began while I was still a PhD student at the University of Minnesota. While finishing a dissertation in paleohydrology, I also had responsibility for coordinating the introductory geology courses that reached hundreds of students in a year and taught the lecture portion of the course for a semester. Being in front of more than 200 students was intimidating, but I also saw it as a chance to express my creativity by finding new ways to keep students engaged, for example, by using the long stairway in the auditorium to create a geological time scale. In my first two faculty positions after graduating, I was drawn to opportunities to work with earth science teachers during summer workshops. At the time, earth system science frameworks were becoming more prevalent, and the teachers were excited to explore ways to teach about the earth as a system and incorporate satellite imagery into their classrooms. From those very positive experiences with engaged teachers, my interest in educational innovation and understanding instructional effectiveness was sparked and never diminished.

Careers don't always follow a linear path, and the turning point in my understanding of geoscience education research as a discipline happened while I was a program officer at the National Science Foundation (NSF). I always had an interest in working at NSF, and thought I would be in the Geosciences Directorate, but unexpectedly a relevant position opened up in what is now the Division of Research on Learning in Formal and Informal Settings (DRL). Suddenly I was working with colleagues who were education researchers, including strong research methodologists, and forced to learn about research design, methodologies, and data analysis in a much more sophisticated way. I never would have even thought to apply to DRL had it not been for a colleague who was rotating back to his university. Yet it was the best thing that could have happened for my career and pathway to becoming a competent geoscience education researcher. Since leaving NSF I have tried to continue to deepen my understanding of methodology, and I draw on the expertise of colleagues whose background and training span education research and the learning sciences, many of whom I met while at NSF.

I am currently the director of a university research center for STEM education, and this position requires that my scope of work be very broad, encompassing all scientific disciplines and multiple grade levels, including undergraduate education. One of our research associates acts as my research partner for geoscience education projects—she is not a geoscientist, but brings a depth of methodological expertise that complements my own knowledge. Our center has a strong portfolio in informal learning, and we are applying research methods from other studies to advance understanding of informal learning in the geosciences. I am a strong advocate for interdisciplinary partnerships, and would advise someone starting out in GER, especially if their PhD is in geological sciences, to seek out a collaborator who is trained in education and/or social sciences, even someone who works outside of science education. In addition to our own staff, I partner with researchers at the Illinois Education Research Council, who have exceptional skills in quantitative analysis of large datasets. All of these partnerships bring a rigor to my studies that I could not achieve in isolation.

GER and Graduate School

Lindsay C. Maudlin, North Carolina State University

My career began with a traditional science undergraduate degree program. I enjoyed the science, but I also acknowledged that I had a passion for teaching. I continued my career by earning a master's degree and starting a doctoral program in the same traditional science area, but my passion for teaching continued to grow as I participated in science outreach at the K-12 level. I stumbled upon a GER graduate program, and then I left one doctoral program for another. The only advice I would give a younger version of myself would be to stumble upon that GER program sooner.

GER and K-12 Audiences

Carla McAuliffe, TERC

Whenever possible, I have translated Geoscience Education Research (GER) to K-12 audiences. This began with my PhD dissertation (Visualizing Topography) and later, at TERC with the Earth Science by Design project (http://www.esbd.org/) and has continued through my current NSF-funded project, EarthScope Chronicles (http://serc.carleton.edu/earthscope_chronicles/index.html). I am interested in translating geoscience education research to K-12 teachers for two purposes: 1) to highlight research-based pedagogical and assessment strategies congruent with the Next Generation Science Standards and 2) to apply findings from the geoscience spatial learning literature. There is also a need to connect Geoscientists with K-12 classroom teachers. Frequently, the stories Geoscientists know and share transcend typical textbook descriptions of Earth science and can be motivating when collaborating with teachers. I also have a keen interest in working with elementary (K-5) teachers as they strive to implement NGSS in the Earth sciences.

Several key papers and presentations influence my thinking:

- Penuel, W. (2016). Classroom Assessment Strategies for NGSS Earth and Space Sciences. Implementing the NGSS Webinar Series, February 11, 2016
- LaDue, Nicole D., Julie C. Libarkin, and Stephen R. Thomas. "Visual Representations on High School Biology, Chemistry, Earth Science, and Physics Assessments." Journal of Science Education and Technology 24.6 (2015): 818-834.
- Rivet, A. E. and Kastens, K. A. (2012), Developing a construct-based assessment to examine students' analogical reasoning around physical models in Earth Science. J. Res. Sci. Teach., 49: 713–743. doi: 10.1002/tea.21029
- Libarkin, J.C., and Schneps, M.H., (2012). Elementary children's retrodictive reasoning about earth science: International Electronic Journal of Elementary Education, 5(1), 47-62.

I am keenly interested in connecting with others interested in translating K-12 GER into practice as well as conducting research with others in this population.

Best practices for teaching in the field based on research-based evidence

David Mogk, Montana State University

Geoscientists have an implicit understanding that "field work is good", and their instructional practice is based largely on prior experience. This "practitioner's wisdom" has much validity. But we now understand the importance of proper preparation of students prior to field instruction (e.g., "novelty space"), the importance of embodied learning (in both the physical and social setting of field instruction), and the difficulties encountered by students in creating inscriptions (i.e., their representations of the natural world). A review paper would be useful to identify the barriers to learning that students experience at all stages of field instruction (introductory to independent thesis work, in classes for majors, field courses), and the interventions and activities that can help lower these barriers. Bottom line: be explicit about what you (as a master) are seeing and doing in the field, and why.

What Do I See Images - Crucial Tool to Place-Based Case Studies

Sadredin Moosavi, Rochester Community and Technical College

My interest in geoscience education research arose out of the practical desire to help guide my students' study of the environment by helping them to learn to "read" the landscape in the way that a geologist or student of field natural history would do. I approached this goal by making study of a specific place of the student's choice the framework into which the course content of geology is integrated as analysis tools. Since each student is focused on their own particular place, which they probably cannot visit during the semester, it is important that they have an example place that the entire class can study as a model to follow. I have typically used a site that none of the students have visited but which exhibits features that apply to most content areas discussed in an introductory geology course. To help students "read" the landscape of a place they have never been, I have adopted a strategy I read about in a paper in JGE about 10 years ago in which students are given a picture to analyze during class time. The original paper (the reference for which I have long since forgotten) had students analyze an image projected on the screen by annotating a paper version with their own identifications and interpretations. The image was then discussed with peers and ultimately the whole class before being collected for rapid assessment by the instructor. I have modified this strategy by creating specific "What Do I See?" exercises related to the sample place that the class is analyzing. Each major topic has an image, or a few images, carefully selected to address a particular geologic topic or question. For example, when discussing volcanoes, images of the site and of the clearly volcanic Mt. St. Helens are analyzed as a What Do I See to help students look at landforms and rock types to see if the site in question has a volcanic origin. Another exercise a few weeks later examines images of rocks from the site and compares these to sedimentary structures from a modern beach, again offering clues to some aspect of the sample location's past. The individual exercises are quick to assess and build the student's understanding, topic by topic, as we use these tools to tease out the multi-stage history of the class example. Having a physical paper copy to write on and share with peers is an excellent collaborative learning tool that demonstrates in real time the skills and approach to knowledge that we want students to learn over the semester. (It also is a great proxy for attendance!) This approach gives us many of the benefits of a field trip to a place we cannot visit because the same site is visited repeatedly, but viewed through different but related lenses. In the ultimate complement to a geology faculty member...many students internalize this approach to collecting evidence for analysis and end up sharing pictures of their places long after the class has ended. The images have clearly been taken to highlight evidence that addresses a hypothesis about their place, which the student is excited to confirm with their former instructor. Most of these students are NOT geology majors!

Bringing InTeGrate Modules into the Community College Classroom

Elizabeth Nagy-Shadman, Pasadena City College

Two overarching goals drive the InTeGrate (Interdisciplinary Teaching about Earth for a Sustainable Future) Project, an NSF-funded, STEP (STEM Talent Expansion Program) Center Grant spanning 2012-2016. These are (1) the development of curricula that dramatically increase geoscience literacy of all undergraduate students, and (2) the preparation of a workforce that can address current and future environmental and resource challenges. A major InTeGrate enterprise that addresses both of these goals is the development and classroom testing of a new breed of instructional materials (modules), which are grounded in best practices as described in Geoscience Education Research (GER) studies.

To date there are 12 published (on-line) modules that were each developed over 3+ years by teams of three faculty, and there are 21 more modules in various stage of completion. All materials must meet the criteria defined by a 28-element Curriculum Development and Refinement Rubric before testing begins. This rubric encodes both the overarching goals of the project and research-based principles for effective instruction. All materials must include embedded assessments that can be used to measure student progress toward the stated learning goals. Additionally, the materials are expressly designed to:

- address one or more Earth related grand challenges facing society,
- develop student ability to address interdisciplinary problems,
- improve student understanding of the nature and methods of geoscience and developing geoscientific habits of mind,
- make use of authentic and credible geoscience data to learn central concepts in the context of geoscience methods of inquiry, and,
- incorporate systems thinking.

I briefly describe here two different experiences I have had using InTeGrate materials at Pasadena City College. The first involves repeated teaching of one module (six 60-minute lessons) over several years in my oceanography courses. There is no doubt that re-teaching a lesson several times improves it for the students as well as the instructor. In this particular case, however, I was also using pedagogical techniques that I had only dabbled with in the past. This included gallery walks, a role-playing game, jigsaw activities, class discussions, and small group activities. By the fifth time I taught this module I was much more comfortable with the open-ended nature of these types of activities and more confident to try similar strategies in other classes. Students were markedly engaged and invested in understanding the issues we covered, such as climate change, as a result of the hands-on, active-learning style of instruction.

The second experience involved a single semester in which I replaced about 50% of my traditional laboratory activities in my physical geology class with several InTeGrate modules (18 60-minute lessons). Making so many changes at once was a little overwhelming, but I am going to reteach this same course in Fall 2016 and have many ideas for adjustments and refinements. In large part, this is because I wrote daily reflections directly after each class period. Reading back through those has been invaluable in my redesign for this coming fall. Again I feel that student interest was much higher than in my past courses because of the nature of the activities.

How can the GER community make adoption of research results easier and more widespread? The first step, I think, is to provide motivation to instructors to try something new and possibly out of their comfort zone. In my case, my motivation was external, as I am part of the InTeGrate leadership team. I think offering strategies in small parts is an important tactic. It is a large task to redesign a class, so start small. A focus on new instructors (recent graduate students) would also be a logical place to devote time and resources, perhaps via workshops and short courses.

Strength in Collaboration: Thoughts on Multi-Institution GER

Heather L Petcovic, Western Michigan University

Nearly every GER project that I have tacked over my career has involved a multi-institutional collaboration. Sometimes this means that a group of researchers from different institutions collaborate on the same project, working together on a single problem toward a single goal. Under this model, data collection could be done all at one place/time, or distributed across the researcher's institutions. Sometimes this means that one researcher runs the main project, and other collaborators carry out pieces at their own institutions. Some projects are a hybrid between these models.

I've played the role of both leader and follower in each of these situations. My first large project involved two institutions (four researchers) in which we collected data as a group but went our separate ways with analysis and publication. I've also been a sub-contractor to another institution on a teacher PD project; I served on the project team and had input but they ultimately decided the project course. I have two current multi-institution research projects: one involves data collection on a classroom/field intervention for teaching about remote sensing at two of the four participating researcher's institutions; the other has five researchers and an external evaluator (each at a different institution) all working on broadening participation in the geosciences.

My thoughts on what has made my multi-institution GER successful:

- Clear project goals and working style. Is everyone working on the same problem? Is the work distributed across the institutions, or to be done at one location? Will we go separate ways once the data are collected?
- Clear roles and expectations for the project team. Designate a project leader and make their responsibilities clear (will they convene group meetings? take the lead on publications? do the reporting and HSIRB compliance? settle disputes between group members? set the agenda and direction for the group?). Designate roles and tasks, even deadlines for the group members. It's up to the leader to enforce responsibilities and deadlines, yes, even that sucky job of once again reminding your colleagues that their work is due.
- Having a mechanism for dealing with disagreements (or outright conflict). Should a team member or leader be designated to handle conflicts? Should there be time at meetings to discuss issues? Yes, these will happen so prepare.
- Regular communication, in person if possible. Virtual meeting technology is a life-saver. Personally I prefer virtual meetings to conference calls so I can SEE my colleagues and read their expressions. Plus I don't read long emails, so why should anyone else?
- Having an authorship agreement and revising it regularly. What is the criteria for authorship? Who decides what can be published from this project? These are critical conversations to have early with the full project team.
- Knowing what is possible (and what is not) at each of the participating institutions. Maybe one does not have an HSIRB. Maybe one does not have the equipment or personnel needed. Maybe one is an ideal site for the study.
- Making sure that each collaborator (and each institution) is gaining something from participating in the study. Sure, you can ask for a favor and rely on good will. But if the collaborators and their institutions are all truly invested (for whatever reasons) they are more likely to stick with the project.

My thoughts on how the GER community can help facilitate multi-institution collaborative research:

- Make examples of project management documents available to the community, such as authorship agreements or roles/responsibilities documents.
- Provide training or mentoring on project leadership, handling conflict, and team management. None of us are trained to do this work in graduate school so learning leadership skills can be a hard and lonely road.
- Provide examples and case studies of successful multi-institution project that others can learn from.

Jumping the Career Shark to GER

Vic Ricchezza, University of South Florida

I graduated with my geology BA in 1999. I followed this with a nine year career as an environmental consultant. What started as a need for a job eventually turned into an opportunity for a good living. Motivation was from need for money rather than love of the work. Once I settled down to have a family, became a high school science teacher. In this second career – where I taught Earth Systems and AP Environmental Science – I found a new passion and, finally, a real passion for my work. Unfortunately, I also found students that had no quantitative skills and a pile of bureaucracy and questionable administrative decisions blocking my path, causing me to question my career again.

Researching the idea of teaching elsewhere, I found that I'd likely need a graduate degree, and would respect none for myself but in geology. I decided I'd rather teach college than return to secondary education. I set about finding a program that would fit an area of geology that appealed to me. I found the University of South Florida, School of Geosciences, where they are fostering work in a new Geoscience Education Research (GER) program. I was fascinated by the concept of combining my careers thus far; that is, of becoming an expert geologist and educator who does research on the best practices in undergraduate geoscience education and implementing those practices to produce superior graduates to meet the needs of the field.

In joining this program, I found a sub-specialty in Quantitative Literacy (QL) within GER. My master's thesis (in publication, defended 6-8-16), "Alumni Narratives on Computational Geology (Spring 1997 – Fall 2013)", involved a series of interviews with USF geology alumni who took the computational geology course here and discussed their course experiences, how the course helped them in their personal and professional lives, and what they'd like to see geology students learning in the course today. While many interesting responses were given in these interviews, the most profound were one that spurred what I want to do next for my dissertation work and beyond. I want to shape the responses they gave me, along with information from other meetings and studies (e.g., the Summit on the Future on Undergraduate Geoscience Education) to conduct a national survey regarding how undergraduate programs prepare students for their careers, especially in matters of QL. I am also interested in learning about how diversity is better served through our field, especially for women, as this topic came up in the thesis interviews as well.

My future plans are to complete my dissertation within three years and find a postdoctoral GER fellowship before working as tenure-track faculty at a high activity research university.

If I could speak to my younger self, I'd encourage him to take school and life more seriously and learn how to work hard without the threat of lost work or money. There are few chances in life to make a real difference, so don't pass them up so easily and for so little.

Closing the Gap: Geoscience Education and Education Research to Bring Together Science and Society

Juliette Rooney-Varga, University of Massachusetts Lowell

My education and training lie primarily in the areas of biogeochemistry, microbial ecology, and related sciences. Throughout my scientific career, I have engaged in research related to the carbon cycle, atmosphere-biosphere interactions, and climate change. Beginning in the early 2000's, as evidence of anthropogenic global warming mounted, the role of microorganisms in both amplifying and offering potential solutions to climate change became of increasing interest to me. At that point, my scientific research focused on reinforcing feedback loops between climate change and carbon cycling in Arctic peatlands, as well as the use of anaerobic soil microbial communities to generate carbon-neutral electricity through microbial fuel cells.

While this research was both intellectually stimulating and rewarding, as the scientific evidence for the potentially devastating consequences of anthropogenic global change continued to accumulate, I increasingly found myself trying to assess the 'bigger picture' and to understand research beyond my narrow area of scientific expertise. E.g., How significant was the threat of climate change to human society? What was the role of reinforcing or balancing feedbacks to amplify or dampen our impact? How was society responding to the growing body of scientific knowledge about climate and other global change? As a young student, I was drawn to environmental science because of a belief in the potential for science to inform and guide human decision-making. Yet, as a more seasoned scientist interested in global change, it became clear that the gap between science and societal decision-making was vast and appeared to be growing. My interest in geoscience education and geoscience education research grew out of a desire to understand and contribute to closing that gap. STEM education, writ large, includes science communication and decision support that occur beyond the walls of a classroom. Geoscience education research has also made it clear that some of the most effective educational approaches used in the classroom involve engaging, interactive communication and active decision-making by students. Thus, I view my current work as occurring at the interface of communication, education, and decision-support.

Funding for geoscience education innovation and research is essential to creating opportunities to pursue this work. In my own case, funding from NASA's Global Climate Change Education (GCCE; currently ESTEEM) program and NSF's Transforming Undergraduate Education in STEM (TUES) programs have enabled me to pursue my interests. Also essential to this work is an ability and willingness to work across disciplines and, therefore, to expose your own vulnerabilities (i.e., areas in which you are lacking expertise or understanding). Lastly, it has become increasingly clear to me that traditional academic disciplines (and the natural sciences in particular) have strong cultural norms that can both help and hinder our ability to bring science to a broader societal audience and to our own students. Being aware of those norms, willing to question them, and open to the norms of other disciplines may be a first step towards closing gaps between science and society.

Virtual Brownbags to Expand a Community of Practice

Katherine Ryker, Eastern Michigan University

I am involved in four inter-institutional GER research groups. I was a little surprised when I counted them out! While a couple people are in two of the groups, most are only in one. Two of the groups are working on externally funded projects, a third is actively seeking funding, and the fourth is currently willing to navigate our work on our own time. A huge advantage to working with these groups is that I am constantly stimulated by different people and a wealth of ideas and expertise. This makes my job much more fun.

The biggest initial hurdle to overcome in forming these partnerships is, well, finding those stimulating partners! The primary way I've joined or started inter-institutional research groups is through interactions at GSA, in graduate school, and at the On the Cutting Edge Early Career Workshop. Often, partnerships have come about during relatively informal discussions around a shared topic of interest. Identifying research partners is an area where I believe the GER community can offer additional support, particularly in connecting early career researchers with their colleagues.

As Secretary of NAGT's GER division, I work closely with Dr. Kelsey Bitting (Northeastern University) to put together our monthly newsletter, which goes out to over 300 people. This platform can be used to help researchers identify others within the community interested in exploring an idea together. As part of this effort, we began a monthly GER Spotlight in May 2015, which features a GER scholar sharing their work, current interests and favorite papers. Being featured can raise an individual's profile within the community, and encourage others to reach out to you. (We welcome GER Spotlight nominations here - https://nagt.org/nagt/divisions/geoed/newsletter.) However, a more active mechanism is needed if multiple inter-institutional partnerships are to be formed.

Kelsey and I believe that a valuable addition to the newsletter could be a monthly interest poll, asking members to identify a topic of interest (e.g. themes like spatial thinking or inquiry-based labs, methods like eye tracking or interviewing, or analysis techniques). Based on the most popular choice, the GER division would host a virtual brownbag discussion around a relevant journal article. This would be a time to bring people together from across the country, all of whom are at least a little interested in the topic at hand. I believe that offering these additional opportunities for conversation has the potential to encourage more collaborations. Sometimes, it's just a matter of knowing there's another interested soul willing to tackle a research question with you!

In addition to fostering inter-institutional GER projects, I believe these virtual brownbag discussions could help people get needed advice (a need identified by the GER community survey), and foster a stronger sense of community between meetings, revitalizing and reminding us why we became interested in GER to begin with.

Unpredictable path with strong mentoring

Hannah Scherer, Virginia Tech

My interest in Geoscience Education Research stems from my long-standing interest in teaching and learning, particularly in the geosciences. My involvement in teaching-related professional development as a geology graduate student made me aware of GER and how it can benefit the classroom, but I did not have the opportunity to conduct GER as this training was not available in my PhD program. At the time I decided on a graduate program, I was not aware that this could be a potential career path in the geosciences. Strong mentorship from my PhD advisor and others led me to teaching positions at the secondary and post-secondary levels where I developed a deep understanding of the challenges faced by instructors. My entry into a faculty position in agricultural education was serendipitous and the position I currently hold is unique. One of the aspects of this position that has benefited me greatly is the support I received from my department head to gain the training I needed in education research. I was hired because of my content area expertise and classroom experience with the understanding that I would need to develop research expertise. This latitude has allowed me to develop a budding research program that is grounded in both practitioner experience and a strong theoretical framework. Starting out, I would not have predicted the path I ended up taking but somehow I ended up exactly where I should be. My advice to my younger self would be to capitalize on every opportunity that arises that gets yourself closer to your goals and seek mentorship from a wide variety of individuals.

Research into Practice: Always Something You Can Do

Steven Semken, Arizona State University

Geoscience-education researchers should always actively challenge all philosophical barriers to implementing tested, peer-reviewed, published work on GER, learning research in general, and best practices in teaching—whether by us or by our disciplinary colleagues. It is incumbent upon us as scholars who keep current in GER to do this, no less than it is for our disciplinary colleagues to integrate new results from geoscience research into their curricula and instruction! (Do remind your disciplinary colleagues of this whenever it is necessary.) The barriers that are harder to surmount are, of course, those of time, expense, and institutional inertia. I have had to contend with all of these, and still do. No matter how busy you are, there is always something you can do! My career in geoscience teaching and geoscience-education research is now well into its third decade, and my teaching has been recognized with the highest awards at all three academic institutions where I've taught—so hopefully, I have something useful to suggest. Below I've shared (in brief) a list of things I've done that have mostly worked for me over the years. Your mileage may vary.

Incremental change: Incremental improvements, no matter how small, are far better than no improvements at all. Make at least some thoughtful changes every time you re-teach a course. Look for ways to integrate a few active-learning and peer-teaching activities into your courses. Review your course content as thoroughly as you do your instructional methods: how wide, how deep? Is it relevant and engaging to your students? Be aware of potential personal, linguistic, or cultural conflicts in the classroom or field (e.g., novelty-space issues). Treat student course evaluations as you would any other data: be wary of low response rates and self-selection, but pay attention to what students thought worked and didn't work: especially their qualitative written responses.

New or redesigned courses: The easiest way to integrate sound research and best practices into teaching is to build them in from the ground up. Or, if there are courses in your catalog that have languished for lack of faculty or student interest, adopt one and revivify it with effective research-based methods and current content. While doing that, look into the possibility of having your course count for general-education credit. There is nothing like a bump in enrollment to get your peers (and administrators!) aware of the value of sound teaching.

Teach teaching: Probably every one of your colleagues teaches at least one course or seminar in his or her research specialty—why not you? Offer a course in GER and research-based teaching and open it to all students (including grad students if you have a grad program). If your institution has a pre-service teacher program (education majors), see if you can add your course to their program as a methods course for their majors.

Participatory action research: Work with your local Institutional Review Board (IRB) to authorize research use of student course work and class observations, and to enable students to participate as co-researchers (e.g., peer evaluators). I make sure to have IRB approval and student consent letters on file at the start of every course I teach.

Grant funding: External funding can buy release time as well as human and material resources for innovative course and curriculum design and evaluation—and it's good for the CV too. Write a proposal to do geoscience-education research that includes a strong component on applying the results to teaching. Apply for funding for a sabbatical devoted to research-based course and curriculum design. Partner with research colleagues on proposals to NSF, NASA, DOE, NIH, etc.; offer to help with or take charge of the Broader Impacts requirements; and write a work plan that integrates learning research into teaching along with the disciplinary research outcomes.

Institutional climate: Do what you can to inculcate your colleagues with a basic understanding of—and respect for—research-based teaching. Freely share your course and curriculum materials. Mentor junior faculty in teaching and encourage them to sign up for early-career workshops such as those by On the Cutting Edge. Offer to review your colleagues' grant proposals for broader impacts if they plan to do something related to teaching (especially NSF CAREER proposals, which put emphasis on teaching). Get involved in your unit's peer teaching-evaluation or program-evaluation efforts and write research-based criteria into the specs. Give seminars and workshops on best teaching practices at faculty retreats or between semesters or quarters. If your unit has a colloquium series with visiting speakers, lobby to invite at least one GER speaker every academic year, and ask her or him to give a hands-on workshop for faculty and students as well as a presentation. Encourage your colleagues to attend Earth Educators' Rendezvouses or short courses and workshops at GSA and AGU, and to participate in Cutting Edge/InTeGrate webinars.

Using GER Results in Course Design

Jennifer Sliko, Penn State University

An important step in designing or redesigning any class is to examine published geoscience education research for guidance on best practices in course design. This is especially true if the class incorporates non-traditional pedagogical approaches (that students may not be familiar with). Hence, when redesigning an introductory physical geology class into an online format, I conducted a literature search for examples of "successful" online classes. Most published literature about online instruction focuses on course design, while literature incorporating geoscience education research examining the success of online courses is less abundant. While the literature describing class activities is helpful in developing the course, choosing which activities to incorporate can be difficult without a universally accepted metric to evaluate those activities. Additionally, most geoscience education research about online pedagogy typically evaluates only a small fraction of the class (or one class activity), while a semester-long evaluation could provide better insight about the overall pedagogical trends in that class.

To facilitate the promotion and translation of GER results into useful online course material, detailed course design should be coupled with the publication of the corresponding GER results. Specific course activities are more readily used if the activities can be easily incorporated into multiple course management systems and the completion of the activities are not dependent on an external online host (which can lead to broken links). Additionally, the GER community should continue to promote details about the tested materials through a broad audience (such as the Science Education Resource Center at Carleton College website). Finally, the publication of GER research in more "traditional" research-based journals (such as Geology, Science, and Nature) will expand the readership of GER.

What would a GER toolbox look like?

Thomas F. Shipley (Temple University) and Carol Ormand (Science Education Resource Center, Carleton College)

This essay draws from our experience with the Spatial Intelligence and Learning Center, an NSF funded Science of Learning Center that aimed to understand and support the role of spatial thinking in STEM education. Over the course of 10 years Cognitive Scientists worked with Geologists to develop tools to support spatial thinking in the context of geoscience education. We learned two key, generalizable lessons from this work: 1. The interrelations among tools is complex and we needed to expand our initial conceptions of what a tool was. 2. A cycle of education design profited from both an understanding of the material to be learned and a theory of what was happening in the mind of the learner.

Tools that characterize learning and learning challenges
It would be helpful to have a sense of the myriad learning challenges in the geosciences. What do students find challenging and which of these challenges are important for instructors? We found that it was helpful to work to characterize spatial thinking challenges in the context of a theoretical structure that identified categories of challenges. The processes of linking classroom learning experiences to the psychologist's categories helped the psychologists be clear about the nature of the categories, and helped the geology instructors by identifying challenges across courses that might have a common psychological cause. These tools take the form of typologies that allow the community to categorize a specific learning challenge as a member of a broader group of challenges that can be measured and improved. In other words, the same cognitive processes may be required to understand geologically disparate concepts. Having a typology of learning challenges allows us to recognize that.

Tools that measure learning
As we developed a sense of the different types of spatial thinking challenges we worked to develop ways to measure specific skills (e.g., volumetric thinking). These tools allowed us to assess each skill (understand how many students had specific difficulties) and to see what interventions improve a specific skill. Developing usable measuring tools required both standard psychometric analyses and an understanding of the nature of the spatial thinking errors that novices make (what were likely misconceptions). Notably, this new understanding lead to several important new discoveries in basic cognitive science.

Tools that improve learning
In conjunction with measuring learning, we worked to develop tools to improve learning. We began with general principles from cognitive science (e.g., that externalizing a spatial relation with a sketch or gesture can support thinking about the relationship, and analogical learning is a powerful mechanism to use what is known to learn new spatial information) and worked to apply them to specific learning challenges. Lab studies and small classroom proof-of-concept studies fueled a cycle of design changes where theory and educational practice simultaneously developed. Notably, these learning tools echo common geological teaching practices – gesturing, sketching, analogy – but often with unusual "twists" that make them more effective.

Tools that support the design of new tools
Our research program occurred within the context of a center which supported design in several ways. 1) The tools are not independent (developing tools to improve learning requires characterizing and measuring learning, developing tools to characterize learning is informed by understanding what does and does not improve learning, etc). 2) All tools required experts in psychology, education, and disciplinary science. Developing these tools required colleagues with diverse skill sets working together – people who, in the absence of the center, would not have worked together. This required time, particularly for the development of a rudimentary understanding of and a deep trust in the expertise of colleagues in other disciplines. 3) In addition to the challenge of disseminating findings to groups who do not all read the same journals, improving tools requires some institutional memory of data. Here the geosciences are well ahead of the social sciences in community databases. But notable new databases are now available for the kind of data that is critical for developing tools (e.g., Databrary).

An Example
One outcome of our collaboration has been the development and deployment of the Geologic Block Cross-sectioning Test. Using our earliest conception of the typology of spatial thinking skills in the geosciences, we recognized that penetrative thinking – visualizing the interior of an object – is a key skill, required in most sub-disciplines of the geosciences. Previous

studies (e.g. Kali and Orion, 1996) had identified this challenge and some common novice errors. However, there was not an existing psychometric instrument that measures a person's ability to visualize interiors. (There was a psychometric instrument that measures the ability to visualize the shape of a slice through an object, but it did not require the subject to visualize the interior of that slice.) We used common novice errors to construct the foils – incorrect answers – of a multiple-choice cross-sectioning test. As we deployed the test and our understanding of the cognitive processes and misconceptions developed, as well as how the test might be used, we revised the test – The current test is the seventh revision! Armed with this test, we have been able to evaluate the efficacy of a variety of methods for supporting the development of students' cross-sectioning skills, and to distinguish between subtle variations in those teaching methods. We have then applied the most effective versions of those methods to develop new curricular materials for undergraduate courses in Mineralogy, Structural Geology, and Sedimentology & Stratigraphy.

Collaboration is everything

In the spirit of "the medium is the message," this essay is coauthored by a psychologist and a geologist because we are convinced of the necessity and value of combining social and natural sciences to the goal of understanding the role of the mind in learning and practicing Geosciences.

Metamorphosis: Transitioning into GER

Stefany Sit, University of Illinois Chicago

I began my academic career unaware of Geoscience Education Research. In graduate school I trained to be a seismologist, scanning large amounts of data to study subduction zone processes. In my third year, I started to think more about a career focused on teaching or public outreach. I decided to pursue opportunities to volunteer at elementary and middle schools and participate in teaching enhancement programs. While I initially avoided telling my advisor of my non-seismology related interests, he became a strong supporter of my new goals. He was able to include me on some of his own education initiatives. Together, we developed a new online introductory geoscience course and participated in faculty learning communities. It was through this process that I started to learn more about the educational research community and attempt to implement their results.

As I finished my PhD I started to look for positions that were focused on education. I was lucky to be hired at the University of Illinois at Chicago (UIC), in a position specializing in the practice of teaching. While I had no specific training in education or educational research, the department was excited about the contributions I could make in their courses and my interests to pursue GER. I have now been at UIC for 3 years and I have taken opportunities to build a new network of colleagues by attending conferences, applying for workshops, and inviting educational researchers to campus. I have tried hard to listen intently to the needs and directions of the community. I try to share my ideas, ask others for advice, and be open to feedback and suggestions. I'm also fortunate to work at a larger university, where I've been able to reach out to education researchers in other STEM disciplines and within the College of Education. I've had informational meetings with them to learn about their research and methods. Some have even offered to share tips on submitting IRB proposals and to give me a crash course in SPSS. For me, a large part of transitioning and becoming successful in GER, is reaching out and building a group of supportive colleagues.

In my position at UIC, I wanted to develop a portfolio of GER activity. I started by writing a few smaller grant proposals focused on the science of teaching and learning. Through these smaller projects I have been able to learn more about defining interventions, outcomes, and assessments. My interests in GER also led me to partner with others in my department on a larger NSF project to attract and retain more students into the geosciences. Through this project, I hope to become more integrated into the GER community. Additionally, I will be working more closely and learning from an educational researcher who will be helping us measure the outcomes of our project.

While I am working to transition into GER, it seems that my new interests are also serving as an asset to the seismology community. I help advise on education and outreach initiatives at the Incorporated Research Institutions for Seismology (IRIS). I will also join colleagues this summer to help teach new graduate students entering seismology. And though I am still learning about GER, I am excited to help foster the relationship and respect for GER by seismologists and geophysicists.

Integration and Collaboration are Keys to a Productive and Joyful GER Career

Kristen Ellen Kudless St. John, James Madison Unievrsity

I was not formally trained in GER. I broadened my geoscience research to include GER while I was early tenure track and was tasked with being the liaison with the college of education at my former institution. The reason for this assignment was that the senior colleague who had this responsibility was going to retire I was the lowest rank person in the department and no one else wanted to do it. Teacher education was not valued by my department colleagues at that former institution (at least at that time), but was something that needed to be done so I was tasked to take it on. I ended up really valuing the contacts I made outside of my department because of this new role. While I did not enjoy the bureaucracy and accreditation-feared motivation for most of the work in that role, I really liked the opportunity to think about question like: *what is good teaching, and how do we know?* I also liked applying this to my own teaching, as well as experimenting with different strategies for leading professional development workshops for K-12 teachers.

Fast forward 15 years, and I am at a different geoscience program at a different university. I moved to a department that had a value system that better matched my own, where I was supported to do both geoscience and geoscience education research. Rather than K-12, I shifted my focus on undergraduate curriculum development and undergraduate faculty professional development. These areas replaced my initial K-12 teacher focus because it was increasingly important to me to integrate GER directly with my own situation – my students, my department, and even my geoscience field of study (paleoclimatology). The ability to have an integrated career that included GER became both the motivation and the glue for how I could be happy and productive in my career. It felt efficient and satisfying to consider how GER fit with the others aspects of my career. And it certainly helped with P&T because I could demonstrate the value and relevance and connect to my now integrated career goals. I think using Integration as a central theme in a GER career can help others as well (see Figure 3 St. John, 2015, Editorial: Is There a Better Model for Promotion and Tenure Preparation and Evaluation of Geoscience Education Researchers in Geoscience Departments?, Journal of Geoscience Education: Vol. 63, No. 4, pp. 265-267. doi: http://dx.doi.org/10.5408/1089-9995-63.4.265).

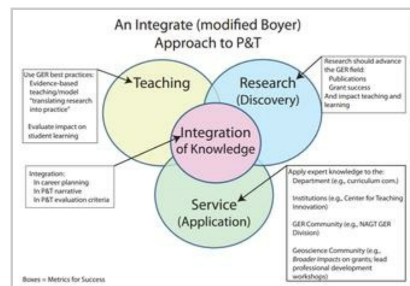

Figure 3 from St. John, 2015, Editorial: Is There a Better Model for Promotion and Tenure Preparation and Evaluation of Geoscience Education Researchers in Geoscience Departments?, Journal of Geoscience Education: Vol. 63, No. 4, pp. 265-267. doi: http://dx.doi.org/10.5408/1089-9995-63.4.265

Collaborations also heavily contributed to my having a productive and joyful career in GER. Some of my collaborators were faculty like me who had a grounding in paleoclimatology and where excited to also study GER. Others were people I didn't already know well, but were acquaintances from meetings who I was interested in learning from and working with. At this stage in my career, it is the collaborations that I value the most - Getting the right group of people together can make a huge different is what can get done and how good it can feel along the way.

So advice for my younger self: Clue in sooner to a negative work environment, do things to change it and/or change your location. Be proactive to educate your colleagues on the importance of what you do and why you do it, without talking down to them or making them feel like that are bad teachers if they take a more traditional approach to teaching than you. Be respectful and open to their questions and feedback. Keep the concept of integration central to your career goals and plan. Remember that good collaboration is the lifeblood of a project. Maintain the collaborations that are productive and joyful, and ease away from those are that not. And be open to new opportunities to collaborate within your program, in different programs across your university, and especially with colleagues at other institutions - that is how good ideas spread and are tested more broadly and greater national impact can be achieved.

My path to DBER - from field geology to geoscience education

Emily Ward, Rocky Mountain College

My path to becoming a Geoscience Education Researcher was a mix of both formal training and apprenticeship in educational research. I became interested in geoscience education when I started working as a TA in graduate school. I started reading the Journal of Geoscience Education to find out more about effective instructional techniques and about how to improve student learning. I sought out a PhD program that would incorporate an element of geoscience education and landed at University of Montana. I completed my PhD in geology and worked on an outreach project with colleagues from Blackfeet Community College to develop field-based outdoor experiences for middle school science teachers. I am grateful for this experience with the Tribal college and reservation schools because it provided me with the opportunity to participate in a project that was important to the local community and effectively blended my love of field geology with student learning. Through our work together on the outreach project, I developed the trust of my Blackfeet colleagues which has led to a sustained research collaboration that is ongoing today.

After completing my PhD, I went on to work as a postdoctoral research associate at the Geocognition Research Lab at Michigan State University where I learned more about the methods and analyses used in discipline based education research. I had the opportunity to audit courses at MSU and learn from some top-notch education researchers in the field. I interacted with other postdoctoral researchers with similar backgrounds to my own, whose formal training was in a science discipline and were interested in becoming aware of the research methods and analyses used by education researchers so that they could employ these techniques as DBERs. Through this experience, I saw that geoscience education encompassed much more than outreach and included basic and applied research on how people think about Earth and understand geological processes.

The advice that I would pass on that has been of use to me in the early stages of my career is to be collaborative. Make connections with those from which you can learn and develop your skills. Take time to build trust in your working relationships. Trust is the essential foundation for sustaining these relationships over time.

Traveling in Multiple Worlds: Geoscience, Education, and Research

Nievita Bueno Watts, Oregon Health and Science University

In another book of my life I worked in P-12 education. I was at times a pre-school teacher, an elementary school teaching assistant, and a high school learning disability paraeducator, but without a teaching credential. At the high school I was able to bridge back to my childhood love of science as liaison between the Special Education and Science departments. Upon the insistence of my students, I began the journey to a teaching credential taking night school courses at the local community college. Then a geologist joined the science teaching staff and I was introduced to Earth Science, which I decided I wanted to teach. So I quit my job and went to study Earth Science education through the Science Teacher Prep Program in the Department of Geoscience at the University of Arizona.

While there I was invited to attend a Society for the Advancement of Chicanos and Native Americans in Science (SACNAS) meeting where I was introduced to the McNair Scholars program and the idea that more minority scientists were needed. After doing a summer internship at HBCU Norfolk State University I realized that I loved research and I was passionate about addressing the problem of minority underrepresentation in the sciences.

I became a McNair Scholar, received a Space Grant, and spent the rest of my undergraduate days working with Mars Orbiter Camera images, looking for signs of ice on Mars while also working on EarthScope digital education database. There was only one course difference between earning a BA in Earth Science Education or a BS in Geoscience, so I decided to take Structural Geology instead of Student Teaching, and apply to graduate School.

I attended Arizona State University under the tutelage of Dr. Steve Semken. There I worked on EarthScope seismometer siting, sense of place research, and research on the visitor experience of deep time cognition at Grand Canyon National Park through the Trail of Time, which was being built. For my Master's thesis work I looked at visitor perception of landscape formation at Petrified Forest National Park.

I pursued my PhD in Science Education, still at ASU, and worked on a large high school science teacher professional development project, Communication In Science Inquiry Project and analyzed elementary student drawings of engineers and robots. But then I returned to my passion to do my dissertation on the barriers and supports Native American student experience while pursuing a tertiary degree in geoscience. After a post-doc at Purdue University, where I worked on an informal science exhibit about gold mining emplaced on the halls of the department, I accepted a position as Director of Academic Programs at a National Science and Technology Center. Here my research skills have been put to use collecting and analyzing data and developing reports, projects, and programs; and I have worked steadily to develop pathways and support for Native geoscientists through the Geoscience Alliance. But now the center has sunset, and I am wondering where the next steps along this pathway will take me...