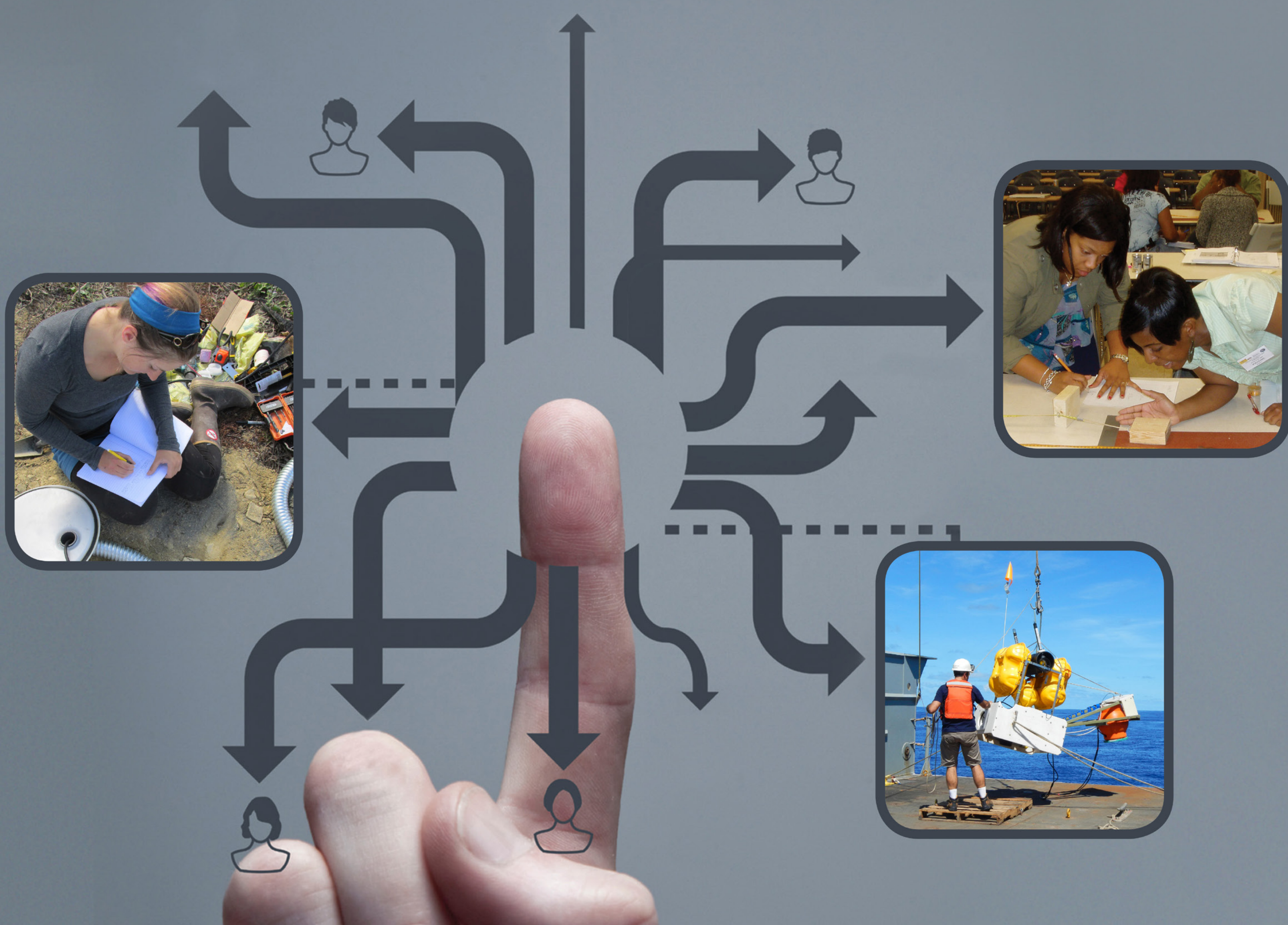
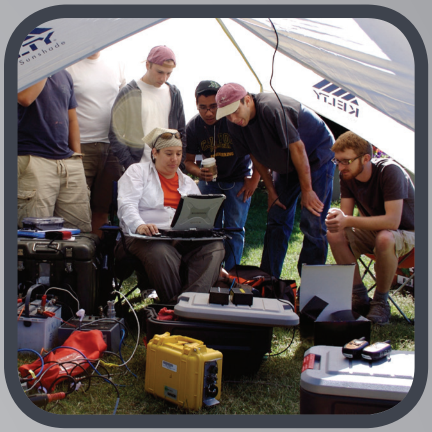
ENGAGE

ENCOURAGING NETWORKS BETWEEN GEOSCIENCE AND GEOSCIENCE EDUCATION

REPORT OF THE WORKSHOP HELD

JANUARY 18–20, 2015 | ARLINGTON, VA





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INTRODUCTION

Discipline-based education research (DBER) investigates questions about teaching and learning within a science or engineering discipline (Singer et al., 2012). Such investigations are particularly important at the undergraduate level, where various disciplines may each require learners to develop distinct skills in addition to constructing content knowledge. Partnerships between discipline-trained scientists and researchers who use social science methodologies can lead to targeted research on key problems impacting the development of such skills within science disciplines. Ultimately, the outcomes from DBER can contribute to a field's self-understanding and enhance its preparedness to equip the next generation to face both current and future challenges.

The geoscience education community has made great strides in the study of teaching and learning at the undergraduate level since early efforts to frame a research agenda was outlined in the meeting report *Bringing Research on Learning to the Geosciences* (Manduca et al., 2004). Building on this foundation, a community of geosciences researchers has collaborated with education and psychology researchers to better understand the nature of geoscience thinking (Manduca and Mogk, 2006; Kastens and Manduca, 2012), and the role of the affective domain in geoscience learning (van der Hoeven Kraft et al., 2011). Concurrently, an effort to raise the awareness of scholarly research in geoscience education was supported through community-scale inreach efforts, such as the National Asssociation of Geoscience Teacher's (NAGT's) "On The Cutting Edge" workshop series and associated website (http://serc.carleton.edu/NAGTWorkshops/index.html). This program sought to influence teaching and learning in the geoscience through professional development of geoscience pracitioners, which included exposure to the research base (Macdonald et al., 2004). The profile and international reach of scholarly research in geoscience education was further enhanced as a result of substantial improvements to the *Journal of Geoscience Education* (Libarkin and St. John, 2011; St. John and Libarkin, 2012).

In parallel with the efforts to advance a geoscience education research agenda, a new generation of researchers have received training in geosciences as well as social science research methods (Feig, 2013). Presently, a community of practice around geoscience education research is emerging as researchers who primarily identify as Geoscience Education Researchers (GER)—DBER scholars who are geoscientists—establish themselves professionally (Lukes et al., 2014). The growing GER network is building the capacity to broaden its research base and significantly influence how geoscience is taught in the future.

As the GER community's research capacity grows, early career geoscience professionals face a new and evolving landscape of what to teach, how to teach, and how to communicate the broader impacts of their research. Geoscientists today are being asked to communicate complex scientific phenomena, such as climate change, to the general public and to use cutting-edge teaching

ENGAGE Workshop Organizing Committee

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- **Jeremy Bassis**, University of Michigan
- **Michael Hubenthal**, IRIS
- **Kaatje Kraft**, Whatcom Community College
- **Nicole LaDue**, Northern Illinois University
- **Peter Lea**, Bowdoin College
- **Shelley Pressley**, Washington State University
- **Beverly Stambaugh**, NSF Liaison
- **Danielle Sumy**, IRIS
- **John Taber**, IRIS

techniques in their classrooms. To address these needs and facilitate a community conversation about geoscience-based education research, the National Science Foundation (NSF) funded the Encouraging Networks Between Geoscience and Geoscience Education (ENGAGE) Workshop, held January 18–20, 2015, in Arlington, Virginia.

This two-day workshop brought together early career scientists from across the geosciences and geoscience educators to promote awareness of geoscience education research among early career geoscience faculty and to catalyze new relationships between geoscience faculty and geoscience education research faculty. These relationships are critical for addressing both the foundational educational research needed on how people learn geoscience content and develop into expert geoscientists, and for facilitating early career geoscientists in enhancing the broader impacts of their geoscience research. Workshop development was led by an organizing committee of nine individuals, many of them early career scientists who have demonstrated interest and commitment to education and scholarship in the geosciences. To ensure that workshop activities would be planned with the needs of the various subdisciplines of the geoscience community in mind, committee membership intentionally spanned the solid Earth, ocean, and atmospheric sciences as well as geoscience education research.

The organizing committee identified the following four goals for the workshop.

1. Engage both geoscience and geoscience education communities in identifying the novel and symbiotic research directions for the future of geoscience education research and establish a list of action items for next steps

3. Nurture future leaders for the geoscience community that are prepared to advance geoscience research and education

2. Promote networking among early career researchers in geoscience and geoscience education to broaden their perspectives and enable cross-disciplinary relationships

4. Develop and share strategies for collaborating and designing competitive broader impacts components of proposals submitted to the Directorate for Geosciences and improve the quality of geoscience-education-related proposals submitted to the Directorate for Education and Human Resources (EHR)

The following report summarizes the recruitment and selection of workshop participants, the design of the workshop and its results, evaluation the effectiveness of the workshop activities in achieving the workshop goals, and ideas and directions for next steps.

PARTICIPATION

The organizing committee sought to recruit ~30 early career (advanced graduate students through pre-tenure faculty), U.S.-based participants from the GER community and a spectrum of geoscience disciplines. Immediately following the launch of the website (http://www.iris.edu/hq/workshops/2015/01/engage_workshop), announcements for the ENGAGE workshop were widely distributed. Communication was disseminated via a variety of discipline specific listservs (e.g., GeoPRISMS, Ocean Carbon and Biogeochemistry, and GER) and general listservs (e.g., Meeting of the Young Researchers in Earth Sciences, and the Early Career group at the Science Education Resource Center), as well as a number of e-newsletter services, including the NAGT and the American Geophysical Union (AGU). To supplement these broad solicitations, hardcopy flyers were prepared and distributed from the NAGT, IRIS, NSF, and UNAVCO booths at both the Geological Society of America and Fall AGU meetings. Finally, targeted advertising was sent via personal email to recent recipients of NSF's Early Career Development awards and other faculty identified by the selection committee.

Applications to participate in the ENGAGE workshop were due only four weeks after the announcements were made to the various communities. Despite this short lead time 102 applications from early career faculty, posdoctoral scholars, and advanced graduate students at U.S. Institutions were received (**Table 1**). Reflecting the demand for the workshop, 16 additional applications were received from international applicants and numerous non-early career faculty inquired about participating if there was an opportunity.

Selection Process

The review and selection of applicants was conducted in two phases. First, the organizing committee conducted an initial review of the 102 applications. Each application was reviewed by at least four members of the selection committee. Preference was given to applicants who:

- Demonstrated some awareness of GER or educational research more generally, as opposed to those that indicated a desire to simply learn new pedagogical techniques or to participate in curriculum writing efforts

- Suggested an openness to new and productive relationships and understandings between early career discipline-based education researchers and physical scientists

Following the initial review, the "short list" was sorted according to the applicants' primary field of study. Each discipline-based list was then reviewed and ranked by pairs from the organizing committee with expertise in that discipline. This second review sought to identify applicants within each discipline that had a strong research portfolio in their field and/or expressed strong interest/plan for participation in the workshop. Offers were then made to the top ranked candidates from each discipline list to create a final 33 person workshop participant list (**Appendix A**).

Table 1. Distribution of ENGAGE workshop applicants and participants by self-identified primary research area. A full description of participants self-identified research area can be found in Appendix A.

	GEOSCIENCE EDUCATION RESEARCH	ATMOSPHERIC SCIENCE	OCEAN SCIENCE	SOLID EARTH	POLAR SCIENCE	OTHER	TOTAL
Applicants	29	6	23	28	10	6	102
Participants	11	3	7	7	3	2	33

Workshop Participants

The selection process resulted in a workshop participant list that represented the primary research areas within the geosciences (**Table 1**). Ultimately, all ENGAGE workshop participants held doctoral degrees but served in various roles within their institutions, with tenure-track faculty as the most common (**Figure 1**). While the majority of participants represented public colleges and universities (n=24), there was participation from private colleges (n=6), one tribal college, and other research institutions (n=2). Nearly all the workshop participants identified as white and not Latino/Hispanic (83.3%), and the majority identified as female (59.4%). A full participant list and aggregate demographic data can be found in **Appendix A**.

To better understand the workshop participants' knowledge of and attitudes toward funding opportunities, education evaluation, GER, outreach, and teaching, a set of 34 items were administered prior to the workshop. Thirty-two of the 33 participants completed this pre-workshop survey. Aggregate responses were used to enable last minute tailoring of the workshop's content. Because participants' experience, perceptions, and attitudes influenced the tone and discussions at the workshop, as well as the resultant recommendations, we present a subset of this information below.

In general, participants had varying levels of experience with and perceptions of GER. For example, prior to the workshop, over 62% of participants indicated that they had participated in education research, while 15% thought participation in education research would be an impediment to their career advancement. Half felt they could distinguish between high- and low-quality education research, and 66% felt capable of distinguishing between education evaluation and education research (**Figure 2**). Over 93% of participants would support a geoscience education researcher as a tenure-track colleague in their department and agreed that GER publications should count toward tenure evaluations.

Participants were also asked about their perceptions of outreach and teaching activities. Over 80% of the participants agreed or strongly agreed that outreach is necessary to inform the public. Yet, less than 50% agreed or strongly agreed that it is an important part of their job as faculty, and one-quarter reported being dissuaded from participating in outreach activities by a colleague, mentor, or advisor. Similar patterns were found regarding participants' perceptions of teaching activities. For example, over 60% agreed that developing teaching activities are an important part of their job, but 22% have been dissuaded from spending a significant amount of time on teaching, and 34% view teaching as an impediment to gaining prestige in their field. Thus, it is not surprising that many early career researchers at the ENGAGE workshop felt that the tenure process should place higher merit on outreach activities (59%) and teaching activities (65%).

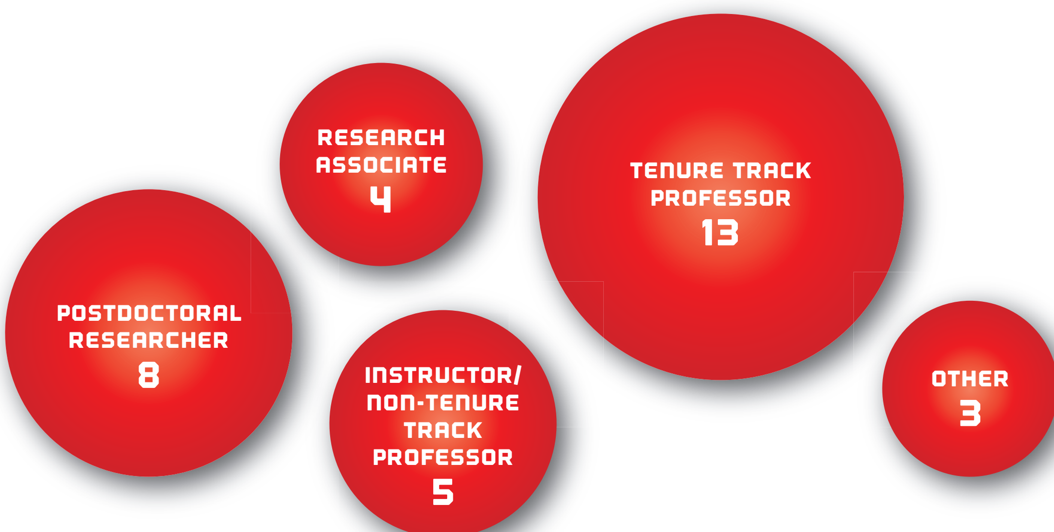

Figure 1. Distribution of ENGAGE workshop participants by position type.

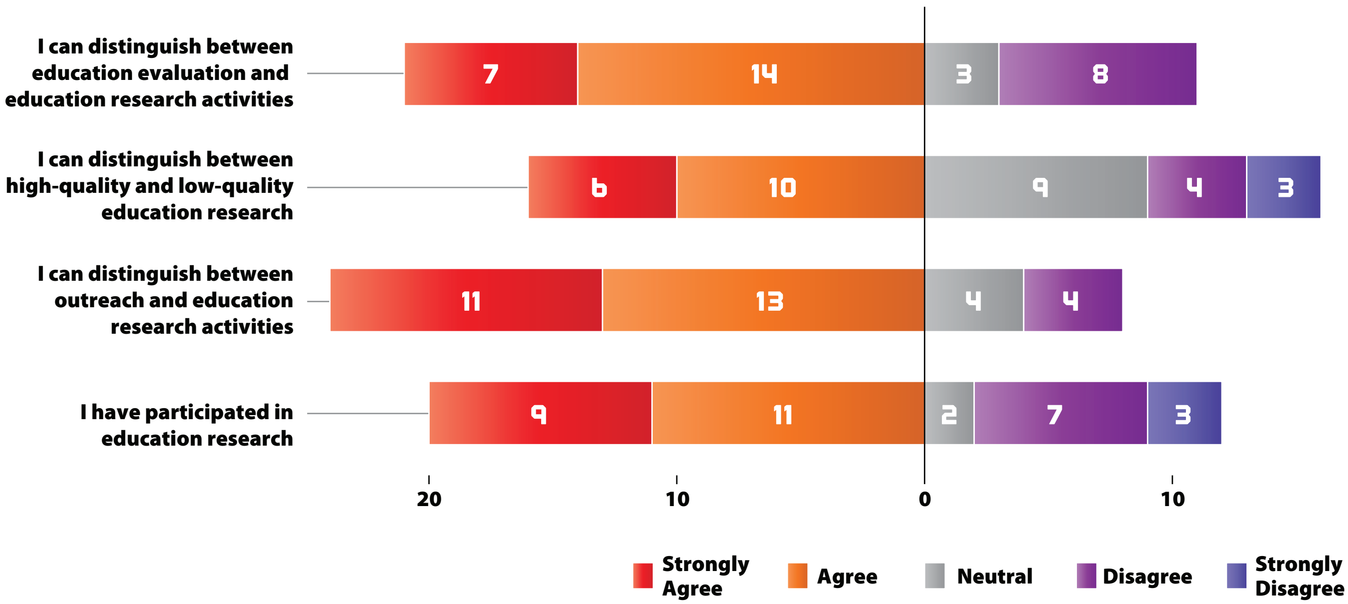

Figure 2. Participant (n=32) agreement with statements about their ability to distinguish among geoscience education research, evaluation, and outreach, and response to a question about whether they are involved with geoscience education research.

Activities and Findings

The workshop agenda (Appendix B) was constructed through a backward design process (Wiggins and McTighe, 1998). Beginning with the goals of the workshop as the desired results, the selection committee defined evidence that supports that the desired results have occurred. Building on this, the organizing committee designed activities employing a spectrum of pedagogical approaches that mapped to the workshop goals (**Table 2**). Through this process, the organizing committee scaffolded both content and concepts in a way that accounted for the content knowledge and cultural differences between the education researchers and the physical scientists.

Pre-Workshop Reading & Facebook Group

Roughly three weeks prior to the workshop, the organizing committee initiated a workshop Facebook Group. The goal of the group was to enable and stimulate conversation among the participants both before and after the workshop.

One week before the workshop, participants were assigned to read several sections of the *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (2012). The following sections were selected as they pertain directly to geoscience education and would help establish a common base level of understanding for all workshop participants.

- Executive Summary (pp 1–4)
- Defining DBER (pp 9–14)
- The Emergence of Geoscience Education Research (pp 28–30)
- Geoscience Education Research (pp 49–50)
- Recommendations (pp 197–203)

Ignite Sessions

With a clear goal of promoting cross-disciplinary networking, participants were given one slide, 24 seconds, and seven words to introduce themselves to the other workshop participants and "ignite" the conversation. This format ensured everyone was heard but no one person monopolized the time allotted for introductions. It also set a lively tone for the workshop and allowed the participants to project a richer image of themselves than other more traditional introductions might. The organizing committee started this process, introducing themselves during the opening remarks the first night of the workshop. The next day, three additional ignite sessions were held for approximately 10 participants each time. The workshop materials also contained pages with all of the workshop participants' pictures and contact information with space to write additional notes during the ignite sessions that could be used for later follow-up conversations both during and post workshop.

Ice Breaker

Prior to the workshop, participants were asked to complete a survey containing items from the Views on the Nature of Science (VNOS) instrument (Chen, 2006). VNOS uses Likert-style questions to understand the participant's views on a number of scientific constructs, including the tentativeness of knowledge, nature of observation, scientific method, imagination, validation of knowledge, and objectivity vs. subjectivity. The VNOS pre-survey also examined the participants' views on the teaching of these scientific constructs.

The resulting data were analyzed ahead of the workshop to create aggregate profiles of the participants and various disciplines represented, and to look for areas of convergence and divergence in their views on the nature of science. Histograms of a sampling of the constructs were presented. Constructs that revealed high agreement across participants included the importance of imagination and the teaching of the tentativeness in science. Participants were consistently neutral on constructs, such as whether

Table 2. Mapping the alignment between workshop goals and core workshop activities. A more detailed version of the agenda can be found in Appendix B.

	KEY SESSIONS	GOAL 1	GOAL 2	GOAL 3	GOAL 4
DAY 1	Organizers and Presenter Ignite Session			X	
DAY 1	Ice-Breaker Activity: Views on the Nature of Science			X	
DAY 1	Homework: Outreach, Education, or Evaluation Case Studies		X		X
DAY 2	Outreach, Education, or Evaluation Case Studies Discussion		X		X
DAY 2	Participant Ignite Sessions			X	
DAY 2	Panel: Status of Geoscience Education Research		X		
DAY 2	Self-Reflection • *What would you like to get out of this workshop?* • *What would you like to do next in your education activities?*		X		
DAY 2	Discipline Group Discussion • *What are the challenges and opportunities within your field?*	X			
DAY 2	Resource Provider Presentations and Resource Fair		X		
DAY 2	Participant Ignite Session			X	
DAY 2	Keynote Speaker: Dr. Heather Petcovic			X	X
DAY 2	Potential Collaborative Research Topics			X	X
DAY 2	Panel: Successful Geoscience Education Projects			X	X
DAY 2	Gallery Walk: Potential Projects	X		X	X
DAY 2	Project Groups or Individual Planning Session	X		X	X
DAY 2	Homework: Community Needs	X		X	X
DAY 3	Project Group Work Time	X		X	X
DAY 3	Group Project Ignite Session	X		X	X
DAY 3	Synopsis & Potential Next Steps	X			
DAY 3	Lunch with NSF Program Officers		X		

GOALS

1. Engage both geoscience and geoscience education communities in identifying the novel and symbiotic research directions for the future of geoscience education research and establish a list of action items for next steps
2. Nurture future leaders for the geoscience community that are prepared to advance geoscience research and education
3. Promote networking among early career researchers in geoscience and geoscience education to broaden their perspectives and enable cross-disciplinary relationships
4. Develop and share strategies for collaborating and designing competitive broader impacts components of proposals submitted to the Directorate for Geosciences and improve the quality of geoscience-education-related proposals submitted to the Directorate for Education and Human Resources

the scientific method is universal or varied, and whether theories and laws are discovered or invented. The construct with the highest variation was how scientists validate scientific knowledge or results. Here, responses fell across a spectrum ranging from completely intuitive, authority (e.g., prestige for person or institution), parsimonious, or paradigm, to completely empirical on the opposite end. Participants were asked to think about where they individually fell along this spectrum and line up across the back of the conference room accordingly. Once on the spectrum, each disciplinary group was asked to step away from the wall, one group at a time. This allowed participants to see where their colleagues fell on the spectrum. There seemed to be great variation across all discipline groups.

Following this, participants paired up with an individual that held differing views to explore how each saw the process of science. Each paring then had an opportunity to introduce their partner and report out. Major themes that emerged from these small group discussions included: (1) that intuition to empirical is not a one-dimensional continuum, because it largely depends on the type of research you are conducting and where you are within the cycle of experimentation and implementation; and (2) there is a need to teach and build scientific intuition, and respect the knowledge and expertise that is gained through a long-term career (authority). For example, intuition can heaviliy influence an initial hypothesis, but there exists an ever-present need to self-monitor your initial assumptions and modify your research design accordingly once empirical data are gathered.

This activity was developed because its focus on the nature of science provided a common point of entry across the diversity of fields, research methodologies, and cultures represented among the participants. Further, the organizing committee sought to foster opportunities early in the workshop to promote networking, cross-disciplinary understandings, and an environment where all perspectives were valued.

Small Group Case Study Analysis

At the conclusion of the first evening, participants were assigned to read several case studies, developed from the organizing committee's professional experiences, and consider if each fit best as "outreach," "education evaluation," or "research" (**Appendix C**). At the outset of the second day of the workshop, participants divided into small heterogeneous groups to discuss the cases and any challenges encountered when defining the boundaries of each category. Following this exercise, each table reported to the entire group.

Through these discussions, the perspectives, knowledge, experiences, and backgrounds of all participants contributed to the conceptualization of each category and their interrelationships, and ideally an internalization of these understandings. Nearly all groups reported that the categorization of the case studies depended on the content and the intended audience or recipient of that content. In general though, most thought that discerning outreach was relatively easy while the distinction between research and evaluation was more complex and nuanced. Discussions frequently emphasized the interrelationships among the three. For example, outreach could be evaluated (e.g., Did it work? Was it a good activity?), and research could be conducted on the outreach approach/evaluation (e.g., Why did they get the results they did?). The development of such understandings supported the workshop goals of preparing participants to advance geoscience research and education and design competitive broader impacts statements for NSF proposals, and improving the quality of geoscience-education-related proposals submitted to the Directorate for Education and Human Resources, and the Directorate for Geosciences.

Discussion Panel: Status of Geoscience Education Research

Two discussion panels were incorporated into the workshop agenda. This format was selected because of its ability to convey information while being highly responsive to the interests and needs of the audience. The first panel was composed of GERers who had received training in educational research methodology during their PhDs or postdoctoral positions and have established research portfolios in distinct aspects of geoscience education. The goal of this panel was to introduce a spectrum of approaches and methodologies of GER. Panelists introduced their research, described how they distinguish among evaluation, research, and the scholarship on teaching and learning (SoTL), and they fielded questions from the audience.

During the question-and-answer segment of the panel, two themes emerged from the physical scientists community. First, many wanted to better understand how a physical scientist gets engaged with DBERs. Panelist noted that the DBER community for the geosciences is very small. However, they noted that connections developed at the workshop could help guide a particular research path. Or, alternatively, a physical scientist could develop a partnership with faculty from education and psychology departments through a local conversation. Panelists noted that such efforts would benefit everyone, as the physical scientists would be simultaneously demonstrating a need for geoscience DBERs or GERs.

Next, the audience wanted to better understand how such collaborations could be supported through NSF funding processes. Here, the panelists and NSF program officers in attendance noted that it was possible for co-investigator arrangements to be established, but funding mechanisms depended on the research question. For example, if the research question is about sedimentary history, and you will create content for a museum display, then the education researcher can come on board as a consultant. If the idea is to study the impact of the museum display on the broader community, the DBER could then be a co-PI in a proposal to an education solicitation. This path goes both ways, in that DBERs need physical scientists, too. In all cases, it is important to understand the scale of what you propose and the budget of such a proposal.

Disciplinary Brainstorming

In an effort to foster thinking that could lead to new research directions for GER, participants were divided into small groups by discipline and encouraged to discuss and clarify major challenges that they and their students have when learning in their discipline. At the conclusion of the session, each group reported on the main challenges identified during their discussion.

- The atmospheric group's discussion focused on the challenges of teaching atmospheric concepts both in class and during outreach events for the general public. Concepts included climate models and related subjects. The audiences struggled to understand discipline-specific data visualizations and graphs.

- The polar group noted challenges with teaching techniques that are used to convey the various spatial and temporal scales of polar science; the development systems-thinking skills in students, which is important because of the multidisciplinary nature of the field; and distinguishing polar science from climate science in the classroom. The group also discussed the limited number of entry points to becoming a polar scientist and the inherent challenges of involving students in fieldwork.

- The ocean group perceived that there is not enough communication between experimentalists, data collectors, and modelers. A related major question seemed to be how to best bridge laboratory work with fieldwork and modeling work. Other challenges included finding opportunities for students to work with instrumentation and data, altering the public's perception of environmental change along coastlines (e.g., sea level rise due to climate change), and explaining complex concepts with simple terminology.

- Participants in the solid Earth group discussed the importance of connecting temporal and geospatial thinking (like deep time on a wide range of scales), the development of skills that allow students to view a concept in different ways, and how to teach and assess the concept of uncertainty. Other challenges included new opportunities in sensor technology and how to use geosciences education research and SoTL results in teaching.

- The DBER group focused on the importance of collaboration within the DBER community, as well as consulting a physical scientist. They also focused on the question of what they can do to give voice from their community to NSF, and the need for institutional support.

Many groups identified topics for which a strong research base already exists within geoscience education or other fields of research, such as communications, psychology, or education. However, in many cases, either the context of geosciences may be a new application of the previous research, or geosciences may couple issues previously discussed in distinct research paths. For example, the atmospheric science group identified challenges with data visualizations and graphs. There is a wealth of literature on this topic in the psychology and learning sciences. However, very little research has been conducted specifically on visualizations associated with atmospheric processes. Furthermore, the compounded problem of helping the general public comprehend the visuals within the context of their personal value systems crosses many disciplinary boundaries. Regardless of the novelty of the topics identified, the activity successfully primed the collaborative conversations to come during the ENGAGE workshop, where the physical and social scientists may find common problems that could lead to fruitful lines of new research.

Keynote Speaker

The organizing committee invited Dr. Heather Petcovic, an associate professor at Western Michigan University, to deliver the workshop's keynote address on interdisciplinary collaboration in geoscience education. Heather was selected because her joint position in an education institute and geology department has allowed her to develop significant experience leading and participating in projects that include geoscientists, education researchers, and cognitive scientists. Key ideas from the talk included the following:

- DIFFERENTIATING INTERDISCIPLINARY VERSUS COLLABORATIVE RESEARCH — Interdisciplinary research means that two different disciplinary researchers combine instrumentation, research design, and data to solve the same problem, while collaborative simply means you play well with others. It was also noted that multidisciplinary projects are yet an additional type as they seek to inform about different projects, but the projects do not overlap or combine.

- CHALLENGES TO PHYSICAL SCIENTIST AND DBER PARTNERSHIPS — The major challenges revolve around the cultural norms (e.g., the myriad different ideas about what constitutes research and the definition of data), practices of different disciplines (e.g., language and jargon, the different types of methods and analyses, human subjects, and dissemination), and existing institutional structures (e.g., the university and department structure and how to publish within these silos). Other challenges include expectations for dissemination, authorship criteria, and how to publish in a dominantly disciplinary journal world.

- BENEFITS OF THE PHYSICAL SCIENTIST AND DBER PARTNERSHIPS — The primary benefit is that a collaborative study can tackle larger problems than one discipline is capable of handling because multiple perspectives improve the work. Other benefits include gaining leadership and project management skills, and building a wide network of collaborators.

- SHARING PRACTICAL TIPS FOR INTERDISCIPLINARY RESEARCH BASED ON EXPERIENCE.
  - Trust each other (find the right people to collaborate with)
  - Test the waters with a pilot study
  - Take time to learn about the disciplinary norms, practices, and expectations of the other disciplines
  - Communicate expectations, consider authorship agreements
  - Above all else, communicate.

Small Group Thought Experiments

To encourage cross-disciplinary thinking and collaboration about learning in the geosciences, participants were placed heterogeneous groups. Each group was asked to examine a list of eight potential collaborative research topics generated by the organizing committee (**Appendix C**), choose one of them to focus on or modify one to suit the interests of the small group, and develop a problem statement that involves the advancement of education and/or broader impacts via collaboration. After the problem statement was formulated, the group was asked to develop three or more related research questions that addressed the proposed problem. While the development of new research directions that could lead to future projects or proposals was a possible outcome, the primary goal was to provide participants with an opportunity to practice working across disciplines and to generate research questions collaboratively. This report intentionally excludes examples of from small group thought experiments to protect the research ideas that some groups are actively pursuing or are planning to pursue.

Participants were asked to write their problem statement and related research questions as a poster. Later in the day, these posters were hung for a gallery walk. During this period, participants examined the posters, added ideas or questions to them using sticky note, and ultimately asked to identify one research question and a few collaborators they wanted to work with to develop a supporting research plan (next day). Seven research themes were defined from the gallery walk process for further development.

Discussion Panel: Successful Geoscience Education Projects

This second panel of the workshop focused on illustrating how collaborations between physical and social scientists could be successful. This panel was composed of faculty trained in either the social or physical sciences who had successfully established productive collaborations with colleagues from outside their traditional disciplines. Given the importance of illustrating these successful collaborations to the workshop goals, two guests, Dr. Jenefer Husman from Arizona State University, and Dr. Carol Ormand from the Science Education Resource Center (SERC) at Carleton College, were invited to join Andreas Andersson from the organizing committee on the panel.

After the brief introduction period covering the panelists backgrounds, the rest of the session was left open for question and answer, as well as broader discussion. The majority of the discussion was process focused on topics such as how to find the right people to work with on collaborative projects and when and how to define authorship. Another strong message from the panel was that all collaborative parties need to think strategically about their interactions (e.g., what they can do pre- vs. post-tenure, what do they really want to get out of the partnership) and be sympathetic to one another (e.g., be careful not to use jargon, since jargon is discipline-specific).

Developing Collaborative Projects

To give participants additional experience working in cross-disciplinary groups and learning from one another, the seven groups that had self-organized during the gallery walk process were given additional time to further develop a research action plan around the research questions that they had identified. Groups were encouraged to consider the process or methods that could be used, the intended outcomes of the work, resources needed, and additional collaborators. Two key products of this work were the development of a written action plan and three to five slides that illustrated the current ideas and issues the groups felt they were still struggling with. As one might expect given the expertise of the various self-selected groups, some of the project ideas were not well informed by the existing education research base. However, when the group reported out their slides to the total group, many participants informally offered to provide support in the form of references and resources to fill these gaps.

NSF Discussion on Broader Impacts

Formative evaluation data collected at the midway point of the workshop suggested that there was a great interest in the topic of broader impacts among the participants. In response, the organizing committee adjusted the agenda to accommodate a short session to share strategies for designing competitive broader impacts components of proposals submitted to NSF. Led by NSF Program Officer Lina Patino, the session opened by describing the evolution of the broader impacts section of the NSF proposal. This discussion was then expanded to provide participants with an overview of the results from NSF's recent "Analysis of Broader Impacts in the Earth Sciences Division" (Lawrence and Patino, 2014).

Brainstorming: Potential Next Steps

The final session of the workshop focused on developing a list of next steps toward the development of a geoscience community that values, and is prepared to benefit from, the integration of a growing community of GERers. Participants were divided into small heterogeneous groups to begin the brainstorming process. Assigning participants to reflect on the following two questions as homework the night before seeded the discussion each groups discussions.

- What does the geoscience community need to move forward?
- What opportunities / resources / support would help the geoscience community develop ideas and foster collaborations between geoscientists and GERers?

Groups recorded their discussions as table notes and then summarized the key ideas as each group reported to the entire workshop. These ideas were captured and edited/modified in real time during a whole group discussion to ensure that all of the ideas were captured correctly. The results of this session are presented later in the section "Concluding Thoughts and Recommendations" (page 19).

EVALUATION

Data supporting the workshop evaluation was collected using two instruments. The first was a formative assessment conducted approximately halfway through the workshop. Participants were asked to provide anonymous written feedback on what they "GOT" out of the workshop so far, and what they still saw as personal "NEED." Twenty-six participants provided feedback on "GOTs" while 29 participants provided feedback on their "NEEDs."

The second evaluation instrument was an optional, online, anonymous post-workshop survey. This survey was conducted onsite immediately following the conclusion of the formal workshop agenda. Of the 33 workshop participants, 30 completed the post-workshop survey before leaving the workshop site. Two of these respondents' responses to the first Likert-type item on the post-survey were completely incongruent with the rest of their responses. This suggested that these respondents misinterpreted that particular scale and responded in reverse. To maintain the integrity of the data set, we opted to remove these participants' responses, leaving a total of 28 responses.

In addition to the data collection instruments described above, the output of the workshop (e.g., notes, documents, presentations) were also examined as evidence.

Organization and Facilitation

ENGAGE participants were asked to rate their perceptions of the workshop's organization and facilitation. As illustrated in **Figure 3**, all ENGAGE participants agreed or strongly agreed that the workshop was well organized and facilitated by the workshop organizing committee.

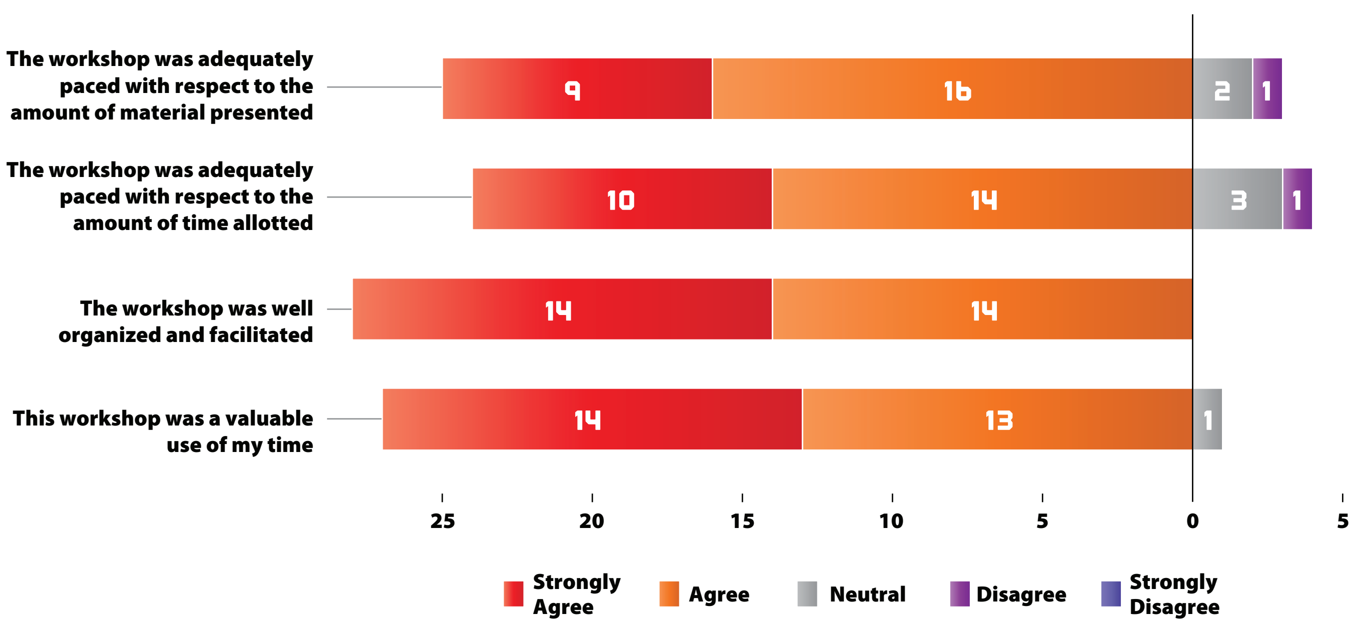

Figure 3. Participants' overall ratings of the ENGAGE workshop were favorable (n=28).

Workshop Agenda

To assess the appropriateness of the workshop agenda overall, and the individual sessions contained within it, participants were asked to rate the pacing of the agenda with regards to the amount of content covered and the amount of time allotted for the various sessions. Participants were also asked to indicate their perception of the workshop as a valuable use of their time and the perceived value of each session in the agenda.

As illustrated in **Figure 3**, 24 of 28 participants agreed or strongly agreed that the workshop was adequately paced with respect to the amount of material presented, while 25 of 28 participants "agreed" or "strongly agreed" that the workshop was adequately paced with respect to the amount of time allotted for the various topics. Moreover, all but one participant "agreed" or "strongly agreed" that the workshop was a valuable use of their time.

Generally, ENGAGE participants found that all the sessions were at least "somewhat valuable" to them. However, as illustrated in **Figure 4**, several sessions were perceived as more valuable than others. Four sessions in particular were perceived as "very valuable" by at least 17 of 28 participants, with nearly all other respondents perceiving these sessions as "somewhat valuable."

- Introductory remarks by NSF
- Outreach, education, or evaluation case studies and discussion
- Project group discussions/group action plan
- Free networking time at breaks, meals, or before/after structured time

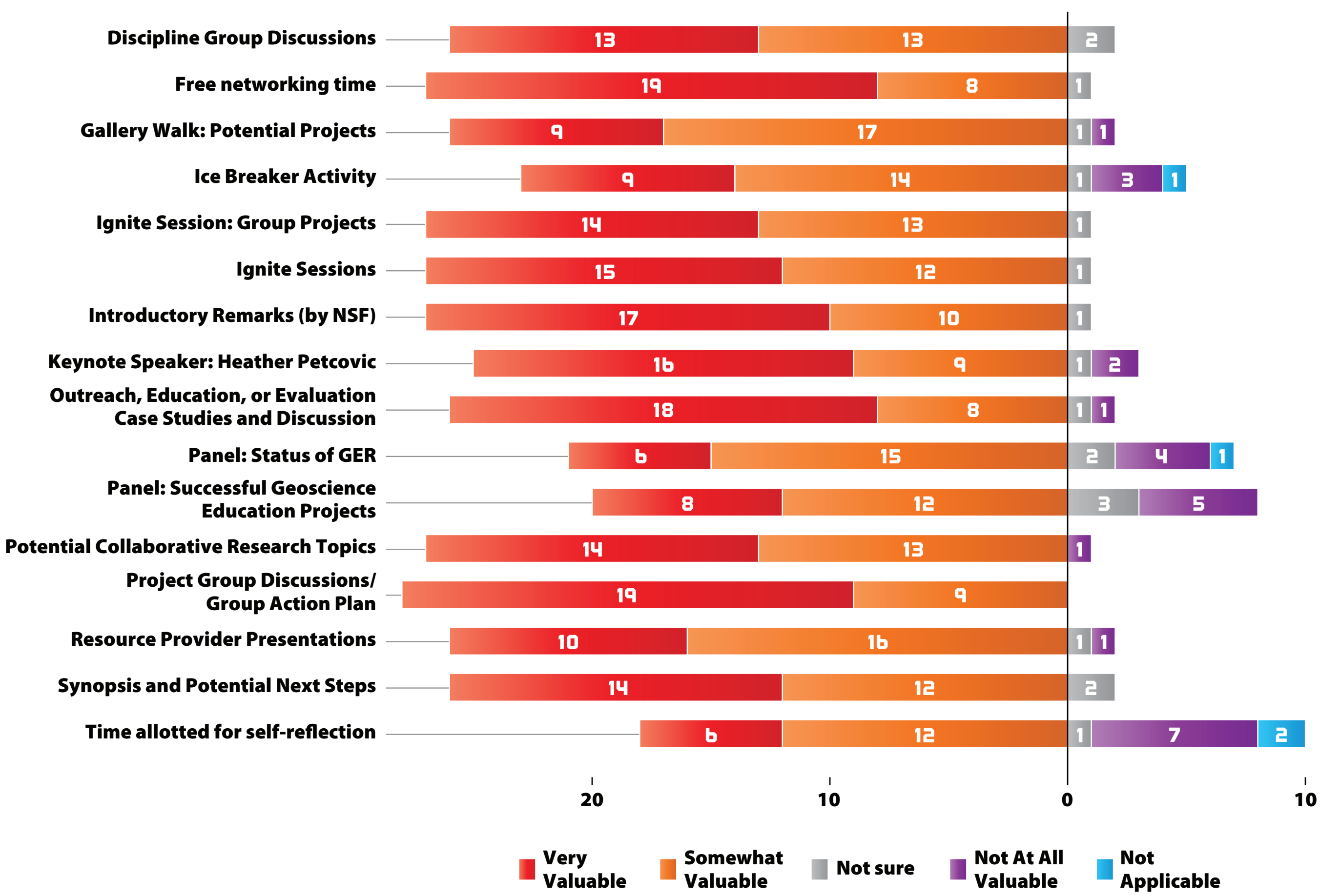

Figure 4. Nearly all sessions included in the ENGAGE workshop provided value to most ENGAGE workshop participants (n=28). One additional session, regarding NSF's review of broader impacts, was not included in this item because it was dynamically added to the agenda.

Conversely, the three sessions perceived as being of less value than the others included the following.

- Time allotted for self-reflection
- Panel: Status of Geoscience Education Research
- Panel: Successful Geoscience Education Projects

It should be noted that the strong value placed on the introductory remarks by NSF may be somewhat inflated due to participants' confounding this session with the dynamically added session on broader impacts also delivered by NSF.

Meeting the Goals of the ENGAGE Workshop

The workshop had four primary goals listed below. Temporally, these goals spanned the workshop itself to some unspecified date in the future. To assess if these goals were met participants were asked to rate their degree of agreement/disagreement with a set of statements about the workshop, and report the likelihood of actions occurring within a year following the workshop.

GOAL 1. Engage both geoscience and geoscience education communities in identifying the novel and symbiotic research directions for the future of geoscience education research, and establish a list of action items for next steps.

The products produced by the workshop suggest that this two-part goal was only partially fulfilled. The first aspect of the goal, "Engage both geoscience and geoscience education communities in identifying the novel and symbiotic research directions for the future of GER," was unfulfilled despite 22 of 28 of participants agreeing or strongly agreeing that they, as a community of participants, "identified research directions for the future of GER." Two factors likely contributed to the workshop's inability to fully achieve Goal 1. First, there was not adequate time allotted to develop the robust conversation necessary to build ideas for the future of GER. Next, and perhaps more importantly, only one-third of the early career participants identified themselves as primarily GERers, a group that would be the most likely to possess a deep understanding of both the history and status of GER. Such understandings would be necessary for nearly all participants to identify novel and symbiotic research directions for the future of GER.

While the workshop was unable to fulfill the first half of the goal, the workshop was successful in establishing a list of action items for next steps. For example, the forward-looking "Synopsis and Next Steps" session was rated as very or somewhat valuable for 26 of 28 participants, and the session successfully generated a list of action items/next steps for NSF and the geoscience community broadly. These action items/next steps are detailed in the "Concluding Thoughts and Recommendations" section of this report (page 19).

Participants' strong agreement that they, as a community of participants, "identified research directions for the future of GER" might actually be attributed to the workshop's efforts to develop symbiotic research directions for possible projects at more of an individual level. The project group discussions/action planning session was identified as "the most valuable" to all participants and a substantial amount of the workshop agenda was dedicated to developing group projects.

GOAL 2. Nurture future leaders for the geoscience community that are prepared to advance geoscience research and education.

Participant responses suggest that the workshop was successful at encouraging the growth of participants with regard to geoscience research and education. Twenty-four of 28 participants "agreed" or "strongly agreed" that they gained new perspectives on geoscience education and research as a result of participating in this workshop (**Figure 5**). This sentiment was mirrored in open responses where participants described how this workshop impacted their thinking and learning about the topic of geoscience education research. The predominate theme emerging from the physical scientists was an increased understanding of GER broadly (e.g., "I got a much better sense of who the community is, what their goals and methods are and how to potentially collaborate with DBERS in the future."), and an increased appreciation for GER (e.g., "I now understand what DEBRs do and find it more interesting than I expected to").

Armed with a new understanding of GER, participants left the workshop with specific plans and intentions to advance geoscience research within their communities. For example, 26 of 28 participants planned to communicate what they have learned from the workshop with their peers (**Figure 5**), and 22 of 28 participants indicated that it was likely or extremely likely that they would seek out new cross-disciplinary connections on their home campus (**Figure 6**). Finally, 27 of 28 participants thought it was likely or extremely likely that they would continue learning about GER within a year of participating in the workshop (**Figure 6**).

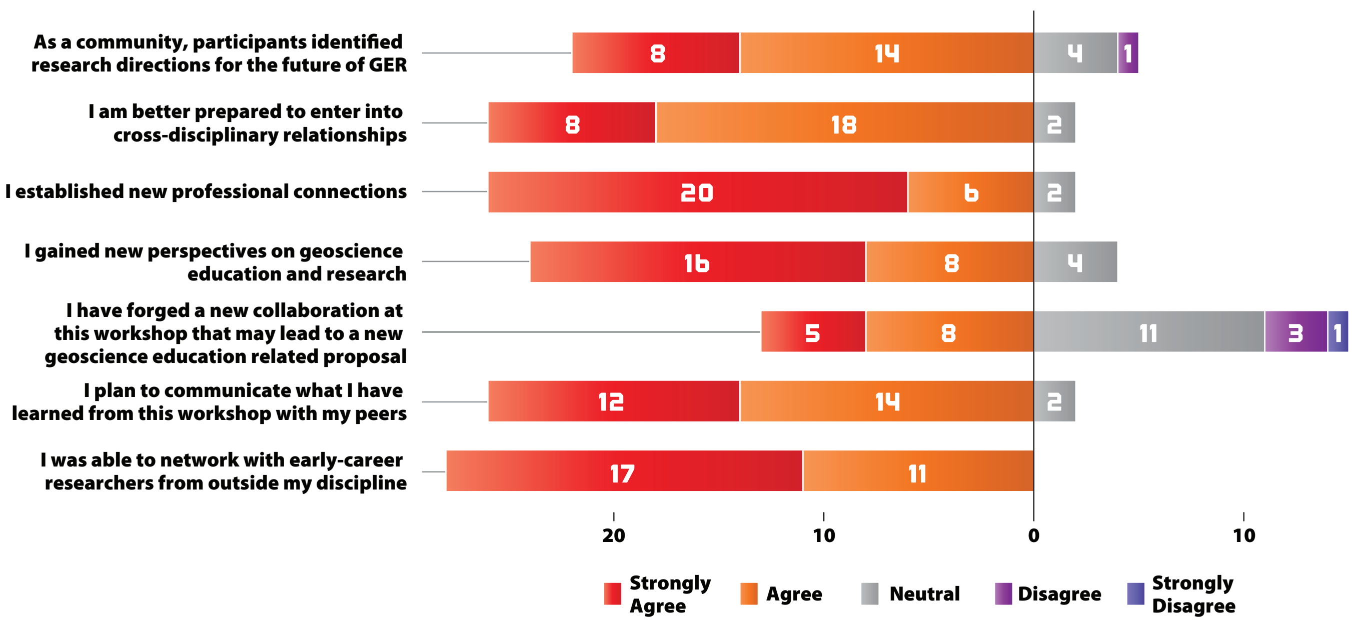

Figure 5. The ENGAGE workshop fostered cross-disciplinary networking among participants (n=28) and enabled most to become better prepared to enter into cross-disciplinary (social and physical science) relationships.

GOAL 3. Promote networking among early career researchers in geoscience and geoscience education to broaden their perspectives and enable cross-disciplinary relationships.

Participant responses indicate that the workshop was successfully able to achieve cross-disciplinary networking and foster cross-disciplinary relationships. All participants agreed or strongly agreed that they were able to network with early career researchers from outside their own discipline at the ENGAGE workshop. This allowed the physical scientists learn about the GERers (e.g., "I learned a lot about what motivates DBERs and how they think/talk; what constitutes DBER research,") and the GERers to learn about the physical scientists (e.g., "I learned a great deal about geoscience specialties and the types of science research people were engaged in, which then leads to areas of interest for ed research"). Through this networking process, 26 of 28 participants agreed that they had established new professional connections as a result of the workshop (**Figure 5**).

Further, 26 of 28 participants agreed or strongly agreed that they were better prepared to enter into cross-disciplinary (social and physical science) relationships (**Figure 5**). As previously mentioned, 22 participants plan to seek out new connections with social/physical scientists on their home campus, while 20 indicated that it was likely or extremely likely that they would collaborate on a research project with a scientist from outside of their discipline (e.g., a social or physical scientist) (**Figure 6**). This is well aligned with open-response data where participants were asked to briefly describe their goals moving forward after the workshop. The predominate theme emerging from the responses focused on building collaborations to support GER. The responses ranged from increasing personal awareness of GER (e.g., "continuing to look for opportunities to learn more about DBER") to planning to seek out colleagues to collaborate on projects (e.g., "network with more DBER faculty on and off my home campus" and "find education researchers on my campus and see what they are working on"). Participants recognized the opportunity they offer to researchers who want to collect data: "Reach out to DBERs for them to use my classroom to do research on questions of interest (changing climate change preconceptions, etc.)" and "serve as a resource." The GER participants also recognized new opportunities for collaboration with physical scientists: "I am interested in finding more opportunities to use the physical scientists as a [sic] expert resources in hopes of understanding some of the unique conceptual challenges in the geosciences."

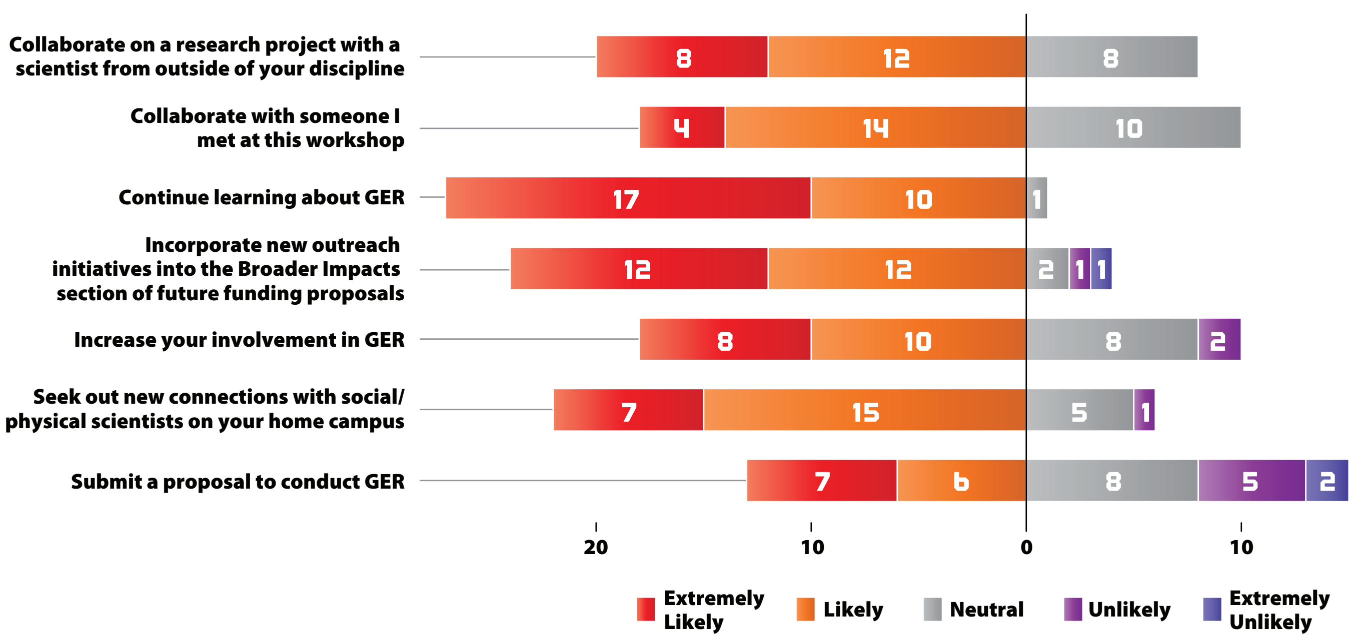

Figure 6. Participants (n=28) indicated that they were likely to continue their learning and engagement with geoscience education research during the year following the workshop.

GOAL 4. Develop and share strategies for collaborating and designing competitive broader impacts components of proposals submitted to the Directorate for Geosciences and improve the quality of geo-ed related proposals submitted to the Directorate for Education and Human Resources.

The nature of this goal only allows the first part, "Develop and share strategies for collaborating and designing competitive broader impacts components of proposals submitted to the Directorate for Geosciences" to be assessed at this time. Here, participant responses suggest that the workshop was successful. As described above, the formative assessment indicated that more information on the topic of broader impacts was needed. The workshop committee responded by modifying the agenda to include a new session dedicated to the topic. As a result, 24 of 28 participants indicated that it was likely or extremely likely that they would incorporate new outreach initiatives as part of the broader impacts section of future funding proposals. This is well aligned with open-response items where several participants commented that they have new ideas for developing stronger broader impacts and outreach components of their work (e.g., "incorporating what I have learned into writing better Broader Impact statement"), while others included broader impacts as part of how the workshop had affected their thinking and learning (e..g., "understanding of the depth of expected broader impacts plans").

The second part of this goal, improve the quality of geoscience-education-related proposals submitted to the Directorate for Education and Human Resources could be assessed through an examination of the funding rates of future proposals submitted to NSF or through longitudinal efforts to track and interview/survey workshop participants. However, such an assessment is outside of the scope of this workshop evaluation.

Suggestions/Feedback

While all but one workshop participant agreed or strongly agreed that the ENGAGE workshop was a good use of their time, participants did provide feedback on what else was needed to have made the workshop even more useful to them. The responses fell into two primary categories (**Table 3**).

Table 3. Categories of open-ended responses for suggestions on what would make this workshop more useful.

CATEGORY	COUNT	EXAMPLES
More time	9	"More time to develop multiple project ideas, less focus on presenters and panels."
		"More time to spread out the intense pace."
		"Perhaps more time spent walking through the process of planning a GER project with mixed physical/social scientist groups would be interesting?"
Additional education/ information on education research	8	"A basic overview of a variety of topics or sub-fields within geoscience education research would have been useful. Maybe some diagrams talking about cognition, thought processes, as well as testing specific pedagogical methods."
		"I would like to have heard more about new methodologies and assessment types, but perhaps that is for a future meeting."
		"…what are the big problems that need to be addressed in GER"
		"…a basic introduction to DBER/Educational Research lingo. A shorter icebreaker and opening presentation on DBER lingo would have been…helpful."

Formative Evaluation

After lunch on the first full day, participants were asked to write down one to three benefits that they had received so far from the workshop (GOTS), plus one to three NEEDS that they still had (anything from logistics to proposed discussion topics), as a formative evaluation of the workshop impact. The GOTS show that even at this early stage, participants were benefiting from the workshop. These GOTS fell into three main categories:

1. An increased understanding of the DBER community and their interests, education research, and the meaning of and the similarities and differences among outreach, evaluation, and education research.

2. New connections and collaborations with other physical and social scientists and an exposure to networks for future collaborations. Sample responses included: "Made a first possible connection with a DBER," and "DBERs are open to offers of collaboration with physical scientists!"

3. An introduction to online resources for teaching, professional development, and educational research.

The NEEDS included a number of topics that were already going to be addressed in remaining sections of the workshop. However, one topic repeated frequently related to creating more effective broader impacts and finding out more about NSF opportunities. To address this need, we modified the agenda on the last morning to include an additional 30-minute presentation and question and answer session led by NSF.

CONCLUDING THOUGHTS AND RECOMMENDATIONS

Evidence from the pre-workshop survey, plus anecdotal evidence from workshop conversations and the large applicant pool for the workshop suggests that many early-career faculty in the geosciences already value teaching, outreach and GER as an important component of being a scientist. As noted previously, this may be in spite of being dissuaded from participating in education and/or outreach activities by a colleague, mentor, or advisor. Thus, this demographic seems primed to become participants in the continued growth and development of a future where geoscience education, GER, and geoscience research are fully integrated.

Building on prior workshops and panels devoted to improving the integration of SoTL and geoscience education research into the broader geoscience community, the ENGAGE workshop represents an intentional step towards connecting and empowering early career physical scientists and GERs. Participants' feedback suggests that these networking opportunities and the workshop professional development sessions successfully broadened their perspectives while empowering them to seek cross-disciplinary relationships with other like-minded early career attendees and/or colleagues at their home institution. We anticipate that these new connections, coupled with the workshop sessions and conversations, will result in new collaborations and new ventures by early career geoscientists and GERers. We also hope to see future leaders of the geoscience community emerge prepared to advance all aspects of the geosciences, including geoscience education and GER.

While much of this work can happen through the individual action of participants, the ENGAGE workshop generated a list of broader, community-wide needs and concerns that if addressed, could assist the further development of a geoscience community that values, and is prepared to benefit from, the integration of a growing community of GERers. These recommendations broadly fell into three categories: resources needed, broadening the impact of GER, and current hurdles to GER.

Resources Needed

A NEW FUNDING MECHANISM to support both the geoscientist and the GERs in a joint project across the NSF GEO and EHR directorates. Participants envisioned two linked proposals, one for science and the other for GER. Presently, the broader impacts components of proposals do not support the quality of work required to study how students learn geoscience topics. The participants envisioned a funding mechanism where the two distinct components—geoscience research and research on learning—are linked. The participants recommend the two components of projects of this type should have distinct panels for merit review.

AN ELECTRONIC NETWORK that would provide opportunities for physical scientists interested in participating in research to meet or learn about GERs looking for collaborators on research. The participants envisioned a profile hosted somewhere that would indicate, for example, the physical scientists' topic, classroom size, and topics covered, and the GER's research type and interests.

A GEOSCIENCE EDUCATION RESEARCH PRIMER, including a summary of promising directions for the field, written for geoscience researchers. This would provide an entry point into the GER domain for interested scientists and would serve as the basis for the construction of a GER community plan. Specifically, the community would like to better understand what is known versus needed with respect to skills and content knowledge.

FUTURE OPPORTUNITIES TO MEET to continue sharing across discipline boundaries that draw both GERs and geoscientists to the table. Participants suggested a range of possibilities, from meetings within larger meeting venues (e.g., AGU Town Hall), webinars, joint workshops, proposal development workshops, to less formal communication through social media or blogs. To maintain the momentum generated at the ENGAGE workshop, an annual meeting (in person or virtual) is suggested.

Broadening the Impact of GER

A DEEPER UNDERSTANDING OF OTHER DBER FIELDS EXPERIENCE would help the geoscience education community understand paths forward to increase the scope and impact of GER.

INCREASING THE NUMBER OF GERs at more institutions, particularly at R1 institutions where there are opportunities to create research programs to train PhDs in DBER and hybrid programs combining geoscience and GER.

DISSEMINATION OF GER to a broader geoscience audience. The participants identified a need to find ways to advertise GER as an avenue for developing stronger broader impacts.

Current Hurdles to GER

SHIFTING FUNDING OPPORTUNITIES present a challenge for new investigators to build upon pilot work targeted toward a particular solicitation.

RECOGNITION WITHIN DEPARTMENTS is needed for researchers to be able to engage in this type of work. In some cases, the culture of the geoscience community and tenure process implicitly suggests that investments of time and energy in GER may be counterproductive to the development of prestige in a researcher's field.

THE PERCEIVED VALUE OF GEOSCIENCE EDUCATION RESEARCH PUBLICATIONS is not equal to publications in other geoscience journals. The participants noted that this is vital for early career researchers to be able to engage with GERs and have that work valued for the tenure and promotion process.

These recommendations are well aligned with the outcomes of earlier reports, and along with those earlier documents, provide the supportive framework for a path forward. In addition, the response to the workshop from the community suggests that early career geoscience faculty, from across a variety of subdisciplines, are interested in enabling or contributing to educational research on how people learn geoscience content and develop into expert geoscientists, engendering a broader acceptance of such work within the geoscience community, and facilitating a much wider distribution of the broader impacts of geoscience research.

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APPENDIX A

ATTENDEE LIST AND PARTICIPANT DEMOGRAPHICS

Organizing Committee

Andreas Andersson, Scripps Institution of Oceanography
Jeremy Bassis, University of Michigan
Michael Hubenthal, IRIS
Kaatje Kraft, Whatcom Community College
Nicole LaDue, Northern Illinois University
Peter Lea, Bowdoin College
Shelley Pressley, Washington State University
Beverly Stambaugh, NSF Liaison
John Taber, IRIS
Danielle Sumy, IRIS

Invited Speakers

Carol Ormond, Carleton College
Jenefer Husman, Arizona State University
Heather Petcovic, Western Michigan University

Participants

Leilani Arthurs, University of Nebraska-Lincoln
Kelsey Bitting, University of Kansas
Caitlin Callahan, Michigan State University
Daniel Carlson, The Florida State University
Lily Claiborne, Vanderbilt University
Tyler Cyronak, Scripps Institution of Oceanography
Nicole Davi, William Paterson University (NJ)
Michael Guidry, University of Hawaii
Rachel Headley, University of Wisconsin-Parkside
Rachel Horak, American Society for Microbiology
Kenneth Hughes, University of Puerto Rico
Marianne Karplus, University of Texas at El Paso
Daniel Lao-Davila, Oklahoma State University
Kateryna Lapina, University of Colorado Boulder
Laura Lukes, George Mason University
Kenneth Mankoff, Woods Hole Oceanographic Institution
Susanne McDowell, Hanover College
Chris Mead, University of Nebraska
Dominike Merle-Johnson, Grand Valley State Univ (MI)
Santosh Panda, University of Alaska Fairbanks
Allen Pope, University of Colorado, Boulder
Henry Potter, Naval Research Laboratory (DC)
Natascha Riedinger, Oklahoma State University
Katherine Ryker, Eastern Michigan University
Regina Sievert, Salish Kootenai College
Stefany Sit, University of Illinois at Chicago
Andrew Steen, University of Tennessee - Knoxville
Aavudai Anandhi Swami, Kansas State University
Sheldon Turner, Northern Illinois University
Emily Ward, Rocky Mountain College
Daniel Westervelt, Princeton University
Kelsey Winsor, Colgate University
Jeannette Wolak, Tennessee Tech University

Participant Demographics

Table 1. Distribution of ENGAGE Workshop participants by gender (n=32).

ANSWER CHOICES	RESPONSES
Female	19
Male	13
Transgender	0

Table 2. Distribution of ENGAGE workshop participants by race and ethnicity (n=30).

	ETHNICITY	
RACE	NOT HISPANIC OR LATINO	HISPANIC OR LATINO
White	25	1
Black or African American	0	0
Asian	3	0
American Indian and Alaska Native	0	0
Native Hawaiian or other Pacific Islander	1	0
White & Black or African American	1	1

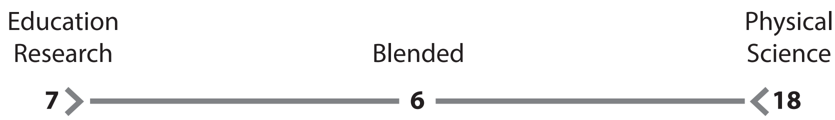

Figure 1: Participants' self-identified fields of study (n=31).

Table 3. Participants' self-identified fields of study (n=31).

FIELD OF STUDY	RESPONSES	%
Education Research	6	19.35%
Solid Earth	8	25.81%
Polar	1	3.23%
Atmosphere	1	3.23%
Ocean	1	3.23%
Other*	4	12.90%
Education Research & Solid Earth	4	12.90%
Education Research & Ocean	1	3.23%
Education Research & Other*	1	3.23%
Solid Earth & Ocean	1	3.23%
Polar & Ocean	2	6.45%
Atmosphere & Ocean	1	3.23%

* Other fields of study as specified by the participants included the following: Climate change, hydrology, and ecological systems; Geocognition; Climate change; Aqueous biogeochemistry; and Limnology.

APPENDIX B
WORKSHOP AGENDA

ENGAGE: Encouraging Networks between Geoscience and Geoscience Education

Holiday Inn, 4610 N. Fairfax Dr., Arlington, VA 22203

DAY 1 – SUNDAY, JANUARY 18TH

5:30 pm	Introduction and Welcome (John, Nicole, Bev, and Danielle) • NSF Remarks: Lina Patino • Ignite Session: Organizers and Presenters
6:00 pm	Dinner
7:00 pm	Ice-Breaker Activity: Views on the Nature of Science (Sheldon & Kaatje)
8:00 pm	Homework: Outreach, Education, or Evaluation Case Studies (Shelley)

DAY 2 – MONDAY, JANUARY 19TH

7:00 am	Breakfast
8:00 am	Participant Ignite Session (Danielle)
8:10 am	Review Agenda (Danielle)
8:30 am	Discussion: Outreach, Education, or Evaluation Case Studies (Shelley)
9:30 am	Participant Ignite Session (Danielle)
9:40 am	Break
10:00 am	Panel: Status of Geoscience Education Research (Andreas) Panelists: Kaatje Kraft, Nicole LaDue, Caitlin Callahan, Emily Ward, Katherine Ryker
11:00 am	Self-Reflection (Kaatje) *What would you like to get out of this workshop?* *What would you like to do next in your education activities?*
11:15 am	Discipline Groups (Kaatje) *What are the challenges and opportunities within your field?*
12:00 pm	Lunch
12:30 pm	Resource Provider Presentations and Resource Fair (John)
1:30 pm	Participant Ignite session (Danielle)
1:45 pm	Keynote Speaker: Heather Petcovic
2:45 pm	Potential Collaborative Research Topics (Nicole & Michael)
4:00 pm	Break

DAY 2, CONTINUED

4:15 pm	Panel: Successful Geoscience Education Projects (Jeremy)
	Panelists: Jenefer Husman, Carol Ormand, Andreas Andersson
5:30 pm	Gallery Walk: Potential Projects (Michael & Nicole)
6:15 pm	Dinner
7:30 pm	Project Groups or Individual Planning Session (Michael & Nicole)
8:00 pm	Homework: Community Needs (Bev)

DAY 3 – TUESDAY, JANUARY 20TH

7:00 am	Breakfast
8:15 am	Plan for Today (John)
8:30 am	Project Groups (Michael & Nicole)
9:30 am	Break
9:45 am	Ignite Session: Group Projects (3 min/group) (Michael & Nicole)
10:15 am	Project Groups
10:30 am	Broader Impacts with Lina Patino
11:00 am	Synopsis & Potential Next Steps (Bev)
11:45 am	Evaluation
12:15 pm	Lunch with NSF Program Officers
1:30 pm	Participants Leave

APPENDIX C
WORKSHOP ASSIGNMENTS

Modification and use of the assignments and case studies developed for use as part of the ENGAGE Workshop are encouraged. If used, please cite this report as the source.

Pre-Reading

Read the following sections from *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering* (2012)

- Executive Summary (pp 1–4)
- Defining DBER (pp 9–14)
- The Emergence of Geoscience Education Research (pp 28–30)
- Geoscience Education Research (pp 49–50)
- Recommendations (pp 197–203)

HOMEWORK 1. OUTREACH, EVALUATION, & RESEARCH CASE STUDIES

INSTRUCTIONS

Please read each of the following case studies. These case studies are examples that illustrate "outreach" or "educational research" or "evaluation." Please decide which category the case study falls within. During the discussion period with your group, you will have the opportunity to share common themes amongst the different classifications.

GOAL OF THIS EXERCISE

This exercise will help participants understand the differences between the three types of activities. In some cases, there are very fine nuances between the different categories. Discussion should highlight the boundaries between the different categories.

CASE STUDY 1. OUTREACH OR RESEARCH OR EVALUATION

Current team members are working with the Ann Arbor hands-on museum to incorporate a temporary (and hopefully eventually permanent) exhibit that involves a hands-on experiment demonstrating (1) how glaciers flow and (2) that solid "things" on short timescales can behave like fluids on longer timescales. The exhibit can be scaled-up by asking students to think about increasingly complex questions, and a version of this experiment can be used in undergraduate classes as well.

CASE STUDY 2. OUTREACH OR RESEARCH OR EVALUATION

Based on informal classroom assessment, it appears that following traditional instruction (e.g., a rubber band analogy), students are able to convey the basic concept of the elastic rebound theory, but they do not fully accept the concept that rocks are elastic. A new classroom demonstration was designed to physically illustrate a rock's elastic property. To test this, sections of a lab are assigned to one of two treatments, or to a control. In the control class, traditional instruction (e.g., rubber band analogy) is used. In treatment 1, the new demonstration is used in front of the class. In treatment 2, the new demonstration is incorporated into a hands-on lab. To document the students prior conceptions of rocks as elastic solids, and assess the impact of the two treatments, pre- and post-assessments are employed. The pre- and post-assessments are designed to measure direct learning of the concept (e.g., rocks are elastic), as well as students ability to apply this concept to novel situations that haven't been introduced yet (e.g., other solids can also be elastic, explaining a diagram of the elastic rebound theory, etc.).

CASE STUDY 3. OUTREACH OR RESEARCH OR EVALUATION

An education group designs a museum display to provide real-time earthquake information. The display includes a large screen map of current seismicity of different regions, a monitor with the list of earthquakes, and a set of mechanical drums showing current ground motion at three locations. A graduate student creates a set of questions to ask museum visitors based on the display design goals, and then spends time watching, tracking, timing, and interviewing museum visitors at two museums where the display is installed. Her results are used to determine whether the display is effective and to inform changes in future displays.

CASE STUDY 4: OUTREACH OR RESEARCH OR EVALUATION

Each student participating in one of five Research Experience for Undergraduates (REU) programs at this institution is given a pre-survey on the first day of the program. The primary questions that the survey hopes to get at include 1) Is there a link between background and participation in REU programs? 2) What is the general motivation for participating in REU programs? 3) Do students' expectations of time spent doing various activities in their REU program change after the REU experience? and 4) Does an REU experience alter their interest in a variety of career options? Students respond to this survey, which includes questions about their motivation for participating (they rank possible benefits from participating in the program including learning what it's like to be a researcher, finding an interesting field of research, learning about graduate school, gaining hands-on experience, publishing, making money, etc.). They also answer questions about how researchers spend their time, for example reviewing the literature, discussing their research, doing experiments in the lab or computer simulations, analyzing the data, and writing/presenting their results. At the end of the 9–10 week REU experience, students are given the same survey.

CASE STUDY 5. OUTREACH OR RESEARCH OR EVALUATION

A professor at a university has teamed up with an educational organization committed to increase the participation of underrepresented minorities in STEM education. The professor and his lab design lesson plans on ocean acidification. They also carry out a 24-hour research study together with 30 middle school students investigating whether seagrasses can counteract ocean acidification at the local scale. The students are involved in all aspects of this cutting-edge research project. At the end of the project, the students report out on the results to local stakeholders.

CASE STUDY 6. OUTREACH OR RESEARCH OR EVALUATION

As part of a project studying the impacts of climate change on agricultural practices, each summer K12 teachers are invited to participate in a 2 day farm field day. Graduate students working on this project are tasked with developing teaching modules with hands-on activities that illustrate the main concepts of specific research topics. The graduate students present the teaching modules to the K12 teachers as part of this farm field day with the hope that the teachers will be able to use the teaching modules in their own classes. The graduate students work in teams and they must prepare assessment type materials to go along with the activities, such as workbook pages or questions, that the teachers can use to evaluate how well their students learned the material.

CASE STUDY 7. OUTREACH OR RESEARCH OR EVALUATION

The professor notices her students struggle with identifying transgressive and regressive sequences in a stratigraphic column. She designs a lab activity using models where students build sequences and write interpretations. On the final exam, she observes that her students perform better on questions where they were asked to interpret stratigraphic sequences. The professor compares her students' performance on the current test to the grades from last year and notices they are much improved.

CASE STUDY 8. OUTREACH OR RESEARCH OR EVALUATION

A professor collaborates with two other universities to implement a new set of exercises in a mineralogy class. The new activities include the same content presented using a different format (e.g., online versus paper and pencil). For each class, half the class will complete a traditional activity and half complete the new activity. The groups assigned to the traditional and new activities switch for each of 6 successive activities so that all students experience 3 traditional and 3 new activities. Each lab activity is followed by the same quiz on the content, regardless of whether students experience the traditional or new activity. At the end of the semester, the professor compares the students' performance on the quizzes and exams to evaluate differences in the traditional and new activities.

CASE STUDY 9: OUTREACH OR RESEARCH OR EVALUATION

Alumni of an internship program are tracked over time to understand how the program influenced their career path. Data collection involves participant attributes (e.g., race, ethnicity, gender, etc), academic path (degrees completed, degree fields, degree institutions), career path (employer, job title, sector, etc) and perceived program impact on career trajectory.

HOMEWORK 2: POTENTIAL COLLABORATIVE RESEARCH TOPICS

INSTRUCTIONS

The list below contains problem statements/scenarios for your table group to consider as stimuli for conducting a "thought experiment" in how the problem might be addressed collaboratively by physical- and social-science researchers and educators. The activity should inform, but not constrain, the development of later project themes undertaken by self-selected groups. You are not required to continue working on the selected topic, but should find useful the kinds of considerations raised from your conversation.

Please scan through all of the topic statements below and

1. select one for discussion,
2. modify one to better suit backgrounds and interests at your table, or
3. come up with your own problem statement that involves advancing education and/or broader impacts via collaboration
4. develop three or more research questions that relate to your problem statement

For the sake of time, your group should try to settle fairly quickly on a problem statement to address (i.e., no need to discuss each possibility up front).

OUTCOME

The group product will include an informal poster that captures the main points of your table's discussion. For your group poster, please include the following:

- Which prompt did you start with?
- Three or more research questions your group developed
- How does this relate to the various geoscience disciplines?

POTENTIAL TOPICS (ARBITRARY ORDER)

1. Having students work with instrumentation to collect their own data appears to increase their engagement in the process and thus improves their ability to interpret the data and draw conclusions about the results. However, there are also plenty of online datasets to allow students to work with real data collected by others. Given that not all institutions can afford instrumentation, could an educational research project be designed to test the differences in student learning between analyzing data they collect themselves vs. finding and using online data?

2. Increasingly, geoscience research utilizes sophisticated numerical models with steep learning curves both in software use and their mathematical basis. What are ways in which such models can be made sufficiently simple and user-friendly to allow undergraduates to explore and understand their conceptual underpinnings? What kinds of expertise and commitments would be needed to bridge the cutting-edge to classroom divide, and what would an educational research plan look like?

3. How do you fully integrate an education program with a cutting-edge research project that allows for simultaneous progress of research and education? Is it possible? What are the limitations and requirements to accomplish this? How is success defined from the two perspectives, and how do you evaluate this?

4. Experts tend to be fluent with abstract graphs that represent 2D and 3D motion (e.g., seismograms, GPS vectors, atmospheric winds, ocean currents), whereas students commonly struggle to make meaning of these representations. What kinds of approaches (e.g., inquiry-based, kinesthetic experiences with motion, wind speed sensors, and flow meters) might improve students' understanding of abstract graphs of motion?

5. Outreach related to some research projects may involve developing museum exhibits for informal science education (e.g., a hands-on experiment demonstrating (1) how glaciers flow and (2) that things that seem like solids on short time scales can behave like fluids on longer time scales) or engagement with K-12 students in the classroom. How do we define and assess the effectiveness of such efforts? What modifications might be needed for different audiences (e.g., grade levels, informal vs. formal)?

6. Nonlinear dynamic systems are notoriously difficult for undergraduate students to master, yet are critical in many societally relevant aspects of geoscience, suggesting that both majors and non-majors should learn (at different levels) the fundamentals of systems thinking. How might physical-science and social science researchers approach a crosscutting effort to address this need?

7. Geoscience departments have a goal of developing students who demonstrate that they have learned something through the course of your program. What are the key elements you want to see in a student after one year in your program, midway through and upon graduation? How would you assure you were consistent with the measurement of this learning across different students in different major tracks?

8. Controversial issues in science (e.g., climate change, evolution) can be challenging to teach, in that many students will have values and hence motivated reasoning on "both sides" of the issue, and because science does not address normative aspects of the intersection with policy. How might instructors best engage students in recognizing and learning the science behind controversial issues and the potential roles of scientists who engage with such issues?

HOMEWORK 3: COMMUNITY NEEDS

INSTRUCTIONS

Over the past two days, we have engaged in discussions, panels, and collaborative work, which have hopefully stimulated your interest and helped to cultivate ideas in geoscience and geoscience education research. Based on that experience, please reflect on the following questions and write down your thoughts and ideas:

1. What does the geoscience community need to move forward?

2. What opportunities / resources / support would help the geoscience community develop ideas and foster collaborations between geoscientists and geoscience education researchers?

3. Any other thoughts, ideas, or questions?


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