On The Cutting Edge Project:
Year 3 Independent Evaluation Report

Submitted to:
Science Education Resource Center
at Carleton College

March 2013

Submitted by

Rockman et al
Research & Evaluation

595 Market Street Suite 2570 • San Francisco, CA 94105-2802 • 415.544.0788 • FAX 415.544.0789
www.rockman.com

Table of Contents

Index of Tables

Introduction

Rockman et al (REA) is collaborating with the Science Education Resource Center at Carleton College to conduct a multi-year independent evaluation of the On the Cutting Edge program, which is currently in its third year. This report summarizes recent evaluation activities and their findings, and suggests some possible next steps for the program evaluation.

The On the Cutting Edge (CE) project supports the professional development needs of faculty, nationwide, who teach in the undergraduate geosciences. Programmatic efforts are directed at three goals to support the needs of the geosciences education community:

- Expanding the number of faculty who participate in a On The Cutting Edge workshop to 50% or more of U.S. geoscience faculty.
- Providing advanced opportunities for engagement with the program that encourage repeated participation, enable ongoing learning, and result in increased changes in teaching practice.
- Improving the project website with expanded resources that are created and reviewed by the geosciences community, and by improving the methods for finding materials through the website.

The CE project provides an integrated series of workshops and web-based resources that help geoscience faculty stay up-to-date with both geoscience research and teaching methods. There are workshops for early career faculty and for graduate students and post-doctoral fellows, a course design workshop, emerging theme workshops, and workshops at professional meetings. Each workshop has a virtual component that supports participants by providing information about the workshop content, a resource collection relevant to the topic, and opportunities for online discussions with other participants and leaders. Following the workshop, web materials based on the workshop experience enable online learning by a broader community and workshop discussion lists are opened to community participation.

The theory of change model for CE (see Appendix A) maps out the basic components of the program and its intended outcomes. The “Implementation” portion of the model describes the target population and the two programmatic activities in which participants might engage. The “Impact” portion of the model describes the short and longer-term outcomes of participation. As an immediate result of attending a CE workshop or visiting the CE website, participants are expected to:

- Advance their knowledge of geoscience teaching and pedagogy
- Learn new strategies for career management
- Develop more positive attitudes toward the geoscience community in general and geoscience teaching in particular
- Gain a greater appreciation for educational research

Evaluation Focus

To date, evaluation efforts by REA have focused on the impacts of CE workshop participation. A significant direction for the overall program evaluation is to investigate how CE is applied by faculty in different career pathways. Particular emphasis has been placed on different categories of geoscience faculty who have participated in the program. These categories have arisen from analyses of responses from the national survey of geosciences education faculty, the Geoscience Teaching Practices (GTP) Survey. The program staff have identified three types of participating faculty: science research faculty, educational research faculty, and teaching faculty. The first faculty type, science research faculty, is primarily characterized as having multiple recent science publications and presentations, but little or no educational scholarship. In contrast, educational research faculty report multiple recent presentations or publications about education and note attending multiple professional development events about teaching and learning. The third group, teaching faculty, consists of faculty who tend to not have many recent publications or presentations in either science or education, and typically have the heaviest teaching loads.

In terms of teaching practices, the program staff have identified three ordered categories of teaching style: traditional lecture, active lecture, and active learning. In CE, active lecture is defined as frequent use of one or more of the following approaches: (a) lecture with demonstration, (b) lecture in which questions posed by the instructor are answered by individual students, and (c) lecture in which the questions posed by the instructor are answered simultaneously by the entire class. Active learning is defined as frequent use of one or more of the following approaches: (a) small group discussion or think-pair-share, (b) whole class discussions, (c) in-class exercises. Traditional lecture describes teaching that does not frequently involve the above teaching strategies and is thus described as a less student-centered approach. More about these teaching style categories is described in the section on findings from the retrospective interview analysis.

Key Evaluation Activities

In Year 1 of the project (October 2010–September 2011), Rockman et al (REA) examined the projects' existing evaluation reports, program publications and instruments in light of the current project's goals. This process included a retrospective analysis of previous data as well as conversations with project staff about On the Cutting Edge's overall theory of change, expected program impacts and measurable indicators of program implementation, progress and outcomes. During Year 2 (October 2011–September 2012), there were two primary evaluation activities completed. One involved an analysis of changes in knowledge and attitudes about best teaching practices using questionnaire data collected before and after CE workshops, and the other involved an interview study of past CE workshop participants. Results from the first evaluation activity were shared in the Year 2 evaluation report during the summer of 2012. The findings from the interviews conducted by REA in 2012 with past workshop participants were shared in an interim report in the fall (see Appendix B) and are briefly recapitulated in this report.

In Year 3 (October 2012–September 2013), REA and CE staff designed a retrospective study of interview transcripts from past evaluation studies of CE; these interviews were not conducted by REA, but by program staff and other past evaluators. This retrospective analysis uses the present characterization of the three primary faculty types (science research, educational research, and teaching faculty) to re-examine past reports of program impact. This effort uses CE participants' responses to the Geoscience Teaching Practices Survey as a point of comparison with findings from the retrospective analysis of interview transcripts to assess the alignment between the different data collection methods. The retrospective study of interview data from past program evaluations is described later in the report.

In addition to the retrospective analysis of interviews, REA and CE staff planned a pilot study of three case studies of teaching practices among past CE workshop participants. The case studies would involve classroom observations and a document review of syllabi and other course materials. We wanted to look for confirmation of findings from self-report data as well as gather contextual data to develop a richer understanding of teaching practices among some CE participants. We particularly were interested in building case narratives for participants in the 2012 interviews. Plans for this study, along with findings from an initial case, are presented in this report. Recruitment is still underway for the two remaining cases.

Another pilot study was interwoven across the above evaluation activities due to our interests in finding linkages across the data collection methods. Interviews and case studies offer ways to develop contextualized and detailed information about different pathways in the CE program, while the GTP survey strives for a nationally representative of undergraduate geoscience teachers and is able to gather responses from a much greater number of program participants. We aimed to learn how findings were consistent and inconsistent between the interviews, case studies, and surveys to identify the opportunities and limitations for making connections among the different data collection methods.

In the next section, we outline our perspectives for this latter, meta-level analysis that examines methodological issues. This is followed by an overview of the 2012 interview study and then more detailed descriptions of the retrospective study of old interview data and the case study effort. Lastly, we conclude with several suggestions for next steps in the evaluation and with a proposed evaluation timeline that is based on some of these strategies.

Review of Alignment across Multiple Methods

An underlying theme for the three sets of evaluation activities presented in this report (contemporary interviews, retrospective study of old interviews, and case study) is that findings were frequently inconsistent across the multiple data collection methods. In general, the fixed categories defined by survey responses did not hold up across the data collection methods. With our initial case study, our brief samples of classroom behavior did not fully align with interview reports or survey responses. Therefore, the findings for our overriding pilot study, which sought to find opportunities and challenges to establishing linkages across methods, largely emphasized the challenges in using such an approach.

There is reason to question the approach of using different data gathering methods as a means for confirming findings. Not only did we find there to be a range of issues in our effort, but others have also discussed these issues elsewhere. For example, in a review[1] of mixed method studies involving a comparison of interviews and questionnaires, the consistency and consensus statistics were weak. The authors discussed possible reasons for the discrepancies, such as the difficulty of fully or accurately recalling information, the common situation of an individual holding conflicting beliefs, responses biased by social desirability (particularly in interviews), and poor wording or construction of questionnaire items. These and other issues are likely involved in our piloting of this methodological approach, which sought to establish linkages between interviews, cases, and surveys. The constructs (faculty type, teaching style) and their measurement may involve a lack of precision, and thus challenges arise in finding consensus or consistency between different data collection methods. Due to our concern about this latter issue, we tried to be highly explicit in how they were defined, and relied on how they were defined in the GTP analyses.

Another obvious challenge with aligning findings across the different methods is the timing of data collection. With the old interviews and GTP survey data, we were presented with data collected over the past decade, and in some cases we were comparing, for example, interview data collected in 2005 with data from the 2012 GTP survey. The factors of time and method were thus confounded. It might be interesting to have interviews and questionnaires conducted at the same time and at two time points to see if alignment improves.

The differences in coverage between the methods and instruments were also a contributing factor. For example, the interviews we analyzed came from several different interview studies, having different purposes and varying protocols. In addition, classroom observations provide a snapshot of a single class session rather than an aggregation of “typical” teaching. Of course, observed teachers can comment on how representative of their teaching the session is, but that information has its limits.

Despite these issues and limitations, it is nonetheless important to utilize mixed methodologies of data collection in order to acquire *complementary* information. That is, different methods can provide us with differing information that helps us develop a richer understanding of the effects and phenomenon under investigation.

In addition, there are strategies that we could employ to improve our chances at finding alignment across methodologies. For instance, common timing of data collection would be a strong advantage. The instruments used in each methodology could be more similarly structured, so that data collection is more purposively aligned. Just as is done within individual instruments, another

[1] Harris, L. R. & Brown, G.T.L. (2010). Mixing interview and questionnaire methods: Practical problems in aligning data. *Practical Assessment, Research & Evaluation, 15(1)*. http://pareonline.net/getvn.asp?v=15&n=1.

strategy to consider is providing a uniform context that participants respond to across the different methodological tools. We could explore these and other strategies to try to address the issues of data alignment discussed above.

Interview Study with Past Program Participants

To assess the influences of CE on teaching practices and career pathways, REA conducted a targeted sample of interviews with past workshop participants representing different career pathways and a range of CE usage patterns. Our intention was to develop an understanding about the changes in teaching practices that have occurred among workshop participants within various pathways of CE use.

Together, REA and CE staff developed an interview protocol aligned with the program theory of change (Appendix A). The protocol was also modeled after interview protocols previously used for internal evaluation studies. Initially, REA conducted pilot testing of the interview protocol with four faculty that represented a range of CE participation levels (one workshop, multiple workshops), career stages (junior, mid-level, and senior), and pathways (education faculty, research faculty, teaching faculty). The protocol was modified after we reviewed the initial interview and again after a review of the next three interviews and discussions with CE staff of what was learned and not learned from prior evaluation efforts.

During this pilot phase of this interview study, REA also administered the 2009 version of the GTP as a baseline survey to the interviewees prior to the interviews. This survey gathers detailed information about respondents' teaching in introductory courses and higher-level courses; thus, it can help inform a rich narrative when combined with the interview data. However, we found it challenging to recruit participants for this effort, and we suspected that the addition of the survey required greater time commitment than CE participants were willing to afford. When recruiting faculty for interviews during July and August of 2012, we no longer administered the survey. We also shortened the interview protocol to further reduce the time required for participation.

Although we had planned to recruit as many as 40 interviewees, we discontinued recruitment when we met our minimum target of 20 so that we could analyze and interpret the data before deciding to continue the interviewing effort. REA conducted a review and thematic analysis of the interviews using transcriptions and notes. The CE program's "features of a strong teaching activity" (Figure 1) was used as a framework to code the data. We developed several narratives of different career pathways (particularly for each faculty type) and provided examples of changes in pedagogical practices to describe ways that CE influences participants. Further details about the study are described in the full report, which is included in Appendix B. The following section outlines the key findings from this interview study.

Key Findings

A primary purpose for the interview study was to compare influence of CE participation on different faculty pathways. Findings suggested that the different faculty types possessed varied views on what constitutes effective teaching practices. All faculty types in this study were equally likely to come away from CE programs with a sense that strong teaching activities should engage students in problem-solving (feature 6) and encourage collaboration and discussion (feature 9), but teaching faculty were much more likely to list additional features (features 4,5,10, & 14) than other groups.

Figure 1. Features of a Strong Teaching Activity

1. Clearly stated learning goals
2. Activities and assessment aligned with intended goal of the activity
3. Activity motivates and engages students; encourages student interest and attention
4. Activity builds on what students already know and addresses their preconceptions
5. Activity is appropriate for a variety of students
6. Activity engages students in independent thinking, reflection, and problem solving
7. Activity provides opportunities for students to improve their understanding incrementally
8. Activity has appropriate balance of guidance and exploration
9. Activity encourages discussion/collaboration
10. Activity has places for students to assess their own learning
11. Activity contains tips for other teachers
12. Activity engages students in data collection & analysis, observation, and experimentation
13. Activity helps students visualize data relationships, geologic processes, or their relationships
14. Activity requires students to integrate and synthesize ideas from different sources/experiences
15. Activity contains accurate scientific information

A challenging issue with the pathways analysis for this set of interview data was that the initially-defined pathways of science researcher, educational researcher, and teaching faculty were not readily distinctive, and it was not always clear which of these faculty types each participant fell under. The initial inclusion of the GTP survey as a precursor data-gathering tool had offered a means to have faculty type and teaching style identified. In retrospect, instead of not including the survey altogether because of our concerns about the time required to complete it, we could have created a modified survey that just targeted the items pertaining to faculty type and teaching style. This issue is further explored in the final section of the Year 3 report, which discusses next steps in the evaluation.

Support was found for CE impacts on both proximal and distal outcomes depicted in the program model. Proximal outcomes included the changes in attitudes towards geoscience teaching and course design, increased pedagogical knowledge, increased science content knowledge, increased knowledge about career management strategies, and increased awareness and ability to use educational research. A theme across these impacts was that instructors had increased their confidence in these areas because of these gains. In addition, they often described how they had gained the confidence and tools to be able to seek out and test new pedagogical knowledge or ideas. Among distal outcomes, frequent examples emerged for improved capacity as a professor and active designing of courses. To a lesser extent, faculty described their contributions to the geosciences community through creating and sharing teaching methods and involvement in leadership activities that benefit geoscience education.

The interviews provided a variety of examples of how instructors shifted to a student-centered teaching philosophy and how they change their teaching methods and the ways they designed courses. Assessment of student level impacts was not a chief aim for this study, so our understanding of student level impacts was limited. Yet, as an example of indirect evidence of influence on student learning, some faculty explained that after they became involved in CE, they created opportunities for students to engage in learning knowledge or skills in content areas that were previously not offered in the courses they taught or even the institution overall.

To address the need for clearer identification of faculty pathways, CE staff and REA then moved to explore the integration of survey data with interview data. This offered the chance to investigate how faculty type and teaching style emerged from the two different data sources. The next steps for the external evaluation were to do a retrospective analysis of previously gathered interviews of CE participants and to look for evidence of repeated themes and areas of continuity and discontinuity between interviews and survey data. The following section describes this study effort.

Retrospective Analysis of Participant Interviews

In late fall 2012, spurred by the findings from the 2012 REA interviews described above, CE and REA staff proposed a re-examination of past CE evaluation interviews that were spearheaded by the program. The idea was for REA to conduct an independent analysis of the past interviews and integrate the findings with recent interview and planned case study findings. REA would then develop an overall summary of what has been learned, with particular emphasis on methodologies that would further the pathways analysis. The integration of interviews, cases, and surveys would provide examples of how the approach would work, and examples of where the challenges or gaps exist. We wanted to see if we could follow a thread from surveys to interviews to case studies, an exploration of a new methodological approach. We were curious as to what we could generalize from cases and interviews to the overall CE network of users.

We sought to explore patterns and test hypotheses, and to investigate which behaviors identified in 2012 interviews were typical in older interview transcripts provided by the program. We started by classifying interviewees within different pathways based on the most recent survey data. With restricted subsets of data provided periodically by CE staff from past (2004 or 2009) or current (late 2012) administrations of the Geoscience Teaching Practices (GTP) Survey, we worked to build linkages between survey data and the interviews. The addition of survey data provided a common metric for identification of faculty type and teaching style. The major caveat is that the survey data was collected in different years; therefore, the data on faculty type and teaching styles was temporally bound and not collected at the same time as the interview data. In other words, different times for data collection make it difficult to compare data collection methods.

Methods

Sample

In Table 1, there is an overview of the three data sources for interviews and the number of cases available for the retrospective analysis. If survey data was unavailable for past interviewees, we did not include those individuals in this integrative analysis. Seventy-one cases were analyzed. Of those cases, 64 (90%) had both faculty type and teaching style indicated from survey data (the survey data was gathered in 2004, 2009, and 2012). For purposes of analysis, we combined the 2004 and 2009 datasets and created variables for the most currently known category for faculty type and teaching style from those two administration years.

For forty cases, we had faculty type identified by the 2012 survey data, which gave us their most up-to-date status. Within this subset, most faculty were educational research faculty (21); there were fewer science research faculty (9) and teaching faculty (10). In contrast, among those who had type identified only by older survey data (mostly through the 2009 GTP survey), the distribution of type was even, with 11 educational research faculty, 10 science research faculty, and 10 teaching faculty.

Table 1. Interview cases with faculty type identified from survey data

Years	Project	Number of interviews with faculty type identified from survey
2005	Phone interviews about workshop impacts	34
2005-2009	Phone interviews about website	10
2007	Face-to-face interviews	27
		Total = 71

If faculty type was not identifiable by the survey data, then we did not include them in this study; however, if type was identified, but the teaching style is not, we did include them. With the analysis, we hoped to reveal similarities and discrepancies with what faculty self-reported through the surveys. Based upon our analysis of 2012 interview data, we anticipated that interviewees' could align with a different category than indicated by survey data. The reasons for divergences can be due to the data collection methods used, variance in interpretation, or differences in when the data was gathered. For most cases, interview data predated survey data. We also assessed the level or extent of evidence availability for faculty type, teaching style, and the use of strategies that have been identified by the CE program as features of a strong teaching activity. We did this by summing the number of codes for each of these categories for each individual.

Interviewees with survey data available were categorized into one of the nine cells within a three-by-three matrix of faculty type by teaching style (see Table 2). The matrix provides one means of portraying the survey-derived distribution of teaching style among the interview samples as a whole. It is heavily skewed to active learning styles with almost no representation of traditional lecture style. Almost all educational research faculty are classified by survey analyses as having an active learning teaching style. Over half of science research faculty have an active learning teaching style, while all but one of the remaining faculty of this type have an active lecture teaching style. Teaching faculty most commonly are classified as exhibiting an active lecture teaching style, with the remainder in that group mostly have an active learning style. A comparison of the distribution for teaching styles between the two sets of survey data (2012 and combination of 2009 and 2004) suggests that there has been a shift or increase towards more participants being classified as educational research faculty, with a roughly equal-sized reduction in the number of science researchers and teaching faculty.

Table 2. Interviewees with both faculty type and teaching style identified by survey

	Teaching Style				
Faculty Type	Traditional Lecture*	Active Lecture**	Active Learning***	Totals	
Educational Research Faculty	0 (2012 survey)	2 (2012 survey)	18 (2012 survey)	20 (51%)	28 (44%)
	0 (2009 or 2004)	0 (2009 or 2004)	8 (2009 or 2004)	8 (32%)	
Science Research Faculty	1 (2012 survey)	2 (2012 survey)	6 (2012 survey)	9 (23%)	17 (27%)
	0 (2009 or 2004)	3 (2009 or 2004)	5 (2009 or 2004)	8 (32%)	
Teaching Faculty	0 (2012 survey)	7 (2012 survey)	3 (2012 survey)	10 (26%)	19 (30%)s
	1 (2009 or 2004)	4 (2009 or 2004)	4 (2009 or 2004)	9 (36%)	
Totals	2	18	44	64****	

** Frequent use (i.e., several times, weekly, every class) of traditional lecture.*
*** Frequent use of (a) lecture with demonstration, (b) lecture in which questions posed by the instructor are answered by individual students, and/or (c) lecture in which the questions posed by the instructor are answered simultaneously by the entire class.*
**** Frequent use of (a) small group discussion or think-pair-share, (b) whole class discussions, and/or (c) in-class exercises.*
***** Seven interviews were not included in this table because they did not have both faculty type and teaching style identified from a single GTP survey administration.*

There were a few important characteristics of the interview data to note. The set of interview transcripts was derived from different evaluation studies, so their purposes diverged in some areas, thus generating different types of data. For example, one set was specifically focused on evaluating faculty use of the CE website. A few interviewees indicated they were not teaching at the time of the interview and may have been in non-teaching leadership positions or outside academia. Lastly, there were several transcripts that were either very brief in length (1-2 pages), incomplete, or presented in note form. This limited the opportunity to find evidence of faculty type and teaching style.

Coding

Faculty Type

Cluster analyses of data from the GTP Survey revealed three main faculty types in the geosciences: science research faculty, educational research faculty, and teaching faculty. The final cluster solution was based on a group of variables pertaining to "participation and engagement in the geoscience teaching community," rather than classroom teaching practices. These variables were:

- Number of presentations on scientific research
- Number of articles published on research
- Frequency of correspondence with colleagues about course content
- Number of talks attended about teaching methods
- Number of workshops attended on improving teaching
- Whether respondent presented on teaching methods or student learning
- Number of articles published about educational topics

Each of these variables pertained to the two-year period preceding the completion of the survey. The bulleted variables listed above provided a beginning point for coding the past interviews. The following key findings about the three main faculty types from earlier, non-REA, evaluation efforts served as a guide for coding the interviews:

- *Science research faculty*. Science research (GR) faculty primarily come from R1 institutions, although some come from non-R1 institutions, and not all faculty from R1 institutions are categorized as geoscience research faculty. These faculty have been characterized as having strong content knowledge in geoscience as evidenced by multiple geoscience research publications and presentations at professional meetings. GR faculty may or may not have strong pedagogical knowledge. A large number of faculty attending Teaching X workshops and Emerging Theme workshops are geoscience research faculty. Metacognition and Data Visualization workshops tend to attract educational researchers.
- *Educational research faculty*. Faculty identified as educational research faculty represent a hypothesized pathway about individuals who conduct some science research, but also pay substantial attention to their teaching. These faculty tend to come in with, or develop early on, strong pedagogical knowledge as evidenced by the number of publications or presentations about teaching methods or student learning. A new hypothesis about this group is that they have different attitudinal and motivational levels or patterns.
- *Teaching faculty*. A third hypothesized pathway is teaching faculty, who are characterized by a limited use of CE workshops, website, and network. Some possible barriers to their more substantial participation may include a heavier teaching load than other types or financial challenges that limit their ability to devote time to professional development or pay for travel to workshops.

Teaching Style

The CE program has identified three teaching styles through factor analysis of survey data: traditional lecture, active lecture, and active learning. Responses to a set of seven items in the GTP Survey are used to identify teaching style. For the set of items, respondents are asked, “In the lecture portion of your course, how frequently do you use the following teaching strategies?” Response options are on a five-point scale of frequency level: 1 (Never), 2 (Once), 3 (Several Times), 4 (Weekly), and 5 (Every Class). The items each identify a different teaching strategy:

- Traditional lecture
- Lecture with demonstration
- Lecture in which questions posed by the instructor are answered by individual students
- Lecture in which questions posed by the instructor are answered simultaneously by the entire class
- Small group discussion or think-pair-share
- Whole class discussions
- In-class exercises

To identify teaching style with GTP survey data, responses indicating Never or Once are grouped as infrequent use, while Several Times, Weekly, or Every Class are grouped as frequent use. Respondents reporting frequent use of traditional lecture are labeled as Traditional Lecture. Active lecture has been defined as involving frequent use of one or more of teaching strategies 2, 3, or 4 (see immediately above), while active learning has been defined as involving frequent use of teaching strategies 5, 6, or 7. As with faculty type, these survey-based methods for identifying teaching style served as a guide for coding the interviews. Many people indicated a change in either their faculty type (due to tenure) or teaching style. These changes were not captured in our coding scheme.

Additional Codes

The CE-identified “features of a strong teaching activity” (see Figure 1) were used as a source for interview codes. Evidence for one-third of the teaching features (5 of 15) emerged in the retrospective analysis of the interviews. The five features are shown in the codebook in Table 3. The last area of topics in the interviews pertained to feedback about the CE program.

Table 3: Codebook

Faculty Type			
	Code	Definition/Indicators	Evidence
Faculty Type (FT)	Science Research Faculty	These faculty members have multiple geoscience research publications and presentations at professional meetings.	*"I'm in a pretty completely research-oriented post doc"*
	Education Research Faculty	These faculty members have attended workshops about improving teaching or have presented on teaching and learning.	*"So realizing that I can do research, I can do educational research, I can, and still be a geoscientist, and that's been quite a revelation"*
	Teaching Faculty	These faculty members have a lower number of publications, presentations and low attendance at teaching and learning workshops	*"I'm an educator, and I don't do as much research."*
	Correspondence with Colleagues	Refers to talking to colleagues about teaching or learning	*"And, actually, while talking to colleagues about this, I found that some of my colleagues who I only know through research are actually heavily into the teaching side. So I've actually opened up a whole new avenue of discussion with people I've known for years."*
	GSA	Involved in GSA workshops/activities	*"and together with one other faculty member in my department, we're actually presenting an abstract at GSA on this"*
	Institution Expectation	Specific teaching/research expectations	*"I had to resubmit two or three years later to become a full professor. And the reason given was it wasn't my research, it wasn't my service, it was that my teaching wasn't at the level that it was at tenure."*

Teaching Style		
	Definition/Indicators	Evidence
General	General discussion of teaching methods	*"One factor is if I'm receptive trying new things, and I see if there's a reason why it might be useful. Another factor is that if it fits into this general framework, in my mind, and if it's something that gives the students more of an exploratory way of trying to learn, then I'll pay more attention to it."*
Lecture that encourages class discussion	Keyword: discuss(ion). Brief questioning or discussion within lecture.	*"I had a picture and the students discuss that"*

Lecture with demonstrations	Mentions an in-class demonstration	*"Getting the students to see the rocks, getting the students to understand the textures of the rocks, getting the students to understand how the minerals interact with each other in the rocks is basically the most important part of the petrology that we can teach."*
Usage of small group discussions or think-pair-share	Mentions instances in which students collaborate and discuss, including think-pair-share activities. More planned and sustained activities than "class discussion" code above.	*"Students were talking to each other when they were doing the problems and they were actually having conversations that made sense."*
Addressing preconceptions	Identifying preconceptions or misconceptions about the sciences among students	*"So I always thought that the earth sciences had an advantage of having so many applications that were really real and relevant for students. But it just, somehow, there is a certain stigma with some students. And that's hard to overcome."*
Change in teaching from CE workshop(s)	As a result of the workshop, the faculty member reports changes his/her approach to teaching.	*"I actually made a batch of changes to my geochemistry course in terms of using more interactive teaching styles and doing group work, I think, and I think they were pretty successful."*
Lab work	Indication of a lab activity	*"Well, I actually had them do a lab, like on a local out crop, and then I had them turn around and modify the lab"*

Features of a Strong Teaching Activity

Features of a Strong Teaching Activity	Indicators/Keywords	Examples
1. Activity motivates and engages students; encourages student interest and attention	Faculty member provides examples of activities in which student response indicated interest, engagement, attention, or motivation.	*"That was, I think, the most exciting for me because there was a lot of student engagement, and everybody was working really hard. I could see the kids getting a lot out of it."*
2. Activity engages students in independent thinking, reflection, and problem solving	Faculty member provides examples of students doing independent work, critical thinking, and problem solving	*"So I started to try to look at how I can make my classes more interactive and get more student input, and instead of just lecturing to them, having them kind of discover things on their own, kind of guiding them toward that. So I think that's really the biggest thing."*

3. Activity encourages discussion/collaboration	Faculty members provide examples of activities in which students are collaborating.	*"Then the students started taking over, made the presentations, and formed teams to make the presentations."*
4. Activity has places for students to assess their own learning	Students participate in activities that require them to reflect on their own learning process	*"I required them to write a reflection. So I gave them a rubric on how to make a reflection that was going to be worthwhile. And I was able to, I think, express a higher expectation of them than I did the first year, and they did step up to the bar for the most part and worked harder."*
5. Activity engages students in data collection & analysis, observation, and experimentation	Students are interacting with data.	*"And so we do a number of real-world problems, or I present the students here is the problem, and then they make a proposal how they might collect information to solve that problem. And then we go out and collect the data, bring that back, analyze it, interpret the date, and then come up with a solution to the problem."*

Program Feedback	
General feedback about program	*"Other things as a result of that conference, I've been, you know, I've been trying to sort of branch out in the kinds of places I'm looking for funding, and research contacts, and things like that. I'm kind of an unusual geoscience person. I'm an oceanographer at Arizona State. But I guess one of the things I got out of the conference, the sort of range of paths is a lot broader and less great than even I get."*
Usage of program resources (web)	When asked about usage of the website, interviewee responded affirmatively.
Workshop feedback	*"I think that one of the difference, one of the things that maybe would be helpful for the workshop is follow-up in that what, you know, being nagged a little bit more perhaps in that if you came out with a goal or a desire to do something, having you done it, what have you done, or some kind of follow-up that, given our workload, would be relatively easy."*

Findings

Indication of Faculty Type from Interview and Alignment with Designation from Survey Data

In the interview transcripts, each example pertaining to faculty type was coded; so, approximately one-fourth of the interviews had examples for two or all three faculty types. Characteristics associated with educational researcher faculty appeared in 26 of the interviews, characteristics aligned with teaching faculty appeared in 25 cases, and characteristics of science research faculty were present in 24 cases. Examples from transcripts for each type are shown in Table 3, above.

Considered somewhat differently, the most recent survey data available for each participant suggested that there were more educational research faculty (44%) than science research faculty (27%) and teaching faculty (30%). In nine instances, the presence of interview examples associated with educational research faculty matched how they were defined from the most recently available survey data. There were seven instances where there was some evidence of being a science research faculty for those cases identified as such by the most recent GTP survey data. Lastly, there were seven additional cases where the transcripts of individuals identified as teaching faculty (by the most recent survey results) provided one or more examples of characteristics aligned with that faculty type. Overall, the data pertaining to faculty type for these two different data collection methods showed a weak level of alignment, with approximately two-thirds of the cases showing inconsistencies.

Indication of Teaching Style from Interview and Alignment with Designation from Survey Data

Although the method for identifying teaching style through the GTP survey is more straightforward than it is for faculty type, since it relies on responses to a single item, it was still challenging to apply the method to the interview analysis. As can be seen in the codebook, Table 3, under the major category of teaching style, there were categories for "lecture with demonstration", "lecture that encourages class discussion", and "usage of small group discussions or think-pair-share". These categories align with three of the seven strategies listed for the teaching style question on the GTP survey. The other strategies did not emerge from the analyzed interviews.

In about one-fifth (18%) of the transcripts, there was mention of teaching involving some type of demonstration, broadly defined. For example, one faculty member described how his CE experience led him to provide students with the opportunity to see the geology he was teaching about:

> *I guess the example that came to mind first was in one of my intro geology classes…we had gone through the part talking about the different rock types, and then we went out on campus and looked at different buildings on campus that had different types of rocks. And I think…that would be, you know, kind of giving them a base in the classroom but then going and getting the hands-on, seeing it, you know, stuff they pass every day and don't even notice.*

In a similar proportion (23%) of the transcripts, teachers talked about using discussions in their lecture-based classes.

> *Students are debating between themselves, so there's this pure debate going back. It's not just me standing up front and sort of weighing in on a topic. But, you know, they're actually*

thinking actively and considering abstract issues. And you can see that in the questions they ask, in the way they interact with each other, and sort of the dynamics of the classroom.

Lastly, there were at least 14 examples of teachers using a form of small group discussion activity or a think-pair-share activity. This category included examples of student group work that was not confined to the classroom:

And the way I teach it is there's a large amount of student-centered learning. And so there's six main topics in the course, and for each topic, I give them a long, maybe two-hour lecture on background and examples and so forth. And then they have to…go out and, individually or in teams, pick a specific topic in the general area and do research and come back with oral presentations on that.

There were three additional sub-categories of responses in interviews that were grouped within the teaching style category: change in teaching resulting from CE workshops, addressing preconceptions, and lab work. As expected based on prior analyses of these interview data, there were many examples of faculty reporting changes that occurred in their teaching after attending one or more CE workshops. In our analysis, 28 cases (39%) provided one or more instances that described a CE-influenced change in teaching.

A small number (6) of faculty explained how their teaching approach involved a big emphasis on addressing students' preconceptions, including misconceptions, about the sciences. This theme mostly pertained to students beliefs or attitudes about the nature of certain fields in the geosciences, rather than about particular scientific concepts.

Features of a Strong Teaching Activity

The third and final major focus of this retrospective study was to investigate evidence of teachers reporting use of the CE "features of a strong teaching activity" (see Figure 1). Five of the 15 features emerged in the transcript analysis. It is important to point out that the presence of these teaching strategies in the transcripts is not an indication that it was self-attributed to CE participation. A breakdown of the evidence levels for these five features, or teaching strategies, is listed in Table 4, below. The number of cases per feature ranged from 4 to 14. There were 14 examples for each of two teaching features: activity engages students in independent thinking, reflection, and problem solving; and activity engages students in data collection and analysis, observation, and experimentation. One faculty participant described a rather simple, yet stimulating activity involving data collection:

I give them a homework throughout Thanksgiving to calculate how much carbon they were producing. And some of them went into a lot of detail. They put down: hairdryer, 20 minutes on Saturday. And then, there were some websites where they could get the conversion. And then, you know, suddenly, they were stunned.

Table 4. Interview Evidence of Strong Teaching Activity Strategies

Feature/strategy	Number of cases with one or more instances	Number of examples per case			
		0	1	2	3
Activity motivates and engages students; encourages student interest and attention	7 (10%)	64	5	1	1
Activity engages students in independent thinking, reflection, and problem solving	14 (20%)	57	12	1	1
Activity encourages discussion/collaboration	4 (6%)	67	4	0	0
Activity has places for students to assess their own learning	7 (10%)	64	6	1	0
Activity engages students in data collection & analysis, observation, and experimentation	14 (20%)	57	13	0	1

We compared the amount of evidence for the above teaching strategies across the three types of faculty, but found little variation. One exception that stood out was for activity involving data collection, which appeared more frequently among both educational research faculty and teaching faculty than among science research faculty.

Additional Themes

A majority of the interviews involved discussion of collaboration and communication with colleagues about teaching. Of the 73% of cases that did touch on this theme, 64% of those had two or more instances of this theme emerging during the interview.

> *The other thing, in terms of the layout of the workshop, is that having time to just talk with the other participants was really valuable for me because there was such a range of backgrounds that there were several people there who had years of experience teaching, but they were trying to get, you know, more feedback on research. Whereas, sort of all of my education has been focused on research, and so we could really just sort of exchange our sort of the expertise we had from our own personal backgrounds. So that was really valuable to me.*

Another major theme across interviews involved the use of CE resources from workshops and the website. Across all three interview datasets, faculty spoke about how they used CE resources to inform their teaching practices. After the 2004 Indian Ocean Tsunami, a CE participant was able to utilize resources, such as a movie about tsunamis, that were made available on the CE website. She explained, “So it was very helpful for teaching, for showing the students sort of how the deformation at the surface linked to actually creating a tsunami wave at the surface.” The same instructor discussed additional resources she was able to use:

There were a bunch of visualizations of strain and sharing of little 2-D blocks with little ellipses and things in them…And I used those in my class and let the students play with them actually on the computer to teach them about simple share and pure share, and the difference between finite strain and incremental strain. So, those were very, very helpful in helping communicate those ideas to the students.

Case Studies of CE Influences on Classroom Practices

Recent interviews conducted by REA with CE participants, combined with evidence from prior evaluation studies of CE, have pointed to positive changes in faculty instructional and assessment methods. As a complement to sources of data based on self-report (i.e., interviews and questionnaires), we are pilot testing the use of a case study approach to gather more independent and objective data about teaching practices. We want to focus on faculty who attribute their teaching practices to the CE program, as revealed through their interviews. The case studies involve several strategies to gather evidence of teacher practices and the extent to which they align with the CE features of a strong teaching activity (see Figure 1). To access more objective sources of teaching practice changes influenced by CE participation, we are both conducting classroom observations of undergraduate courses, and reviewing course materials and curricula vita. This approach can help triangulate self-report sources of evidence about teaching practices after CE participation. In other words, we can assess the extent that instructors engage in the kinds of teaching practices they reported in surveys and interviews.

Observation data gathered both by a member of the REA team and by Reformed Teaching Observation Protocol (RTOP) observers are expected to largely corroborate the instructor self-reports of teaching practices that were gathered through past interviews. For example, in the REA 2012 interview study, respondents—across the three main faculty types—frequently cited ways that students were more active in their courses after their participation in CE; thus, multiple instances should be seen across each observation. By including an analysis of materials for the whole course and consulting with the instructor to gather further detail about the course, we can understand the instructors' interpretation of classroom sessions that we observe (e.g., how they compare either to other sessions in the course or to other courses that they teach). We can also use these observations as points for reference in learning from the instructor about other courses they teach.

The two observation efforts differ methodologically. The RTOP is designed to measure "reformed teaching" of science or mathematics, from kindergarten all the way to graduate level classrooms; with reformed teaching being defined as standards-based and inquiry-oriented. It is a 25-item protocol consisting of five subscales of five rating items each. The sub-scales are:

- Lesson design and implementation,
- Content pertaining to propositional pedagogical knowledge,
- Content pertaining to procedural pedagogical knowledge,
- Student-teacher relationships
- Communicative interactions

These items are rated on a five-point scale, from (0) “not observed” to (4) “very descriptive”. Thus, the maximum score possible on the 25-item protocol is 100. A rating of ‘0’ is described as “characteristic never occurred in the lesson, not even once”, and a rating of ‘4’ is “only if the item was very descriptive of the lesson”. Observers also record their comments about their rating and activities they observe. The RTOP requires highly trained individuals to be observers for it to be used in research; therefore, it was decided that REA would not use it to structure their observations. Instead, the REA observation consisted of taking low-inference notes and using an adapted version of the Science Lesson Plan Analysis Instrument (SLPAI) to provide guidance for additional note taking and another set of ratings about classroom activities.

Another purpose for this study is to investigate involvement in CE and impacts for different pathways. We will focus on further developing of our understanding of how CE leads to teaching and assessment practice changes—and support for those changes—for research faculty, educational faculty and teaching faculty.

Based on findings from the 2012 REA interview study, we expect to observe some similarities between faculty types. For example, we should find evidence across cases of classroom activities with student problem solving and reflection. We also would expect to observe students collaborating and engaged in discussion with peers and the instructor. Although the level of evidence from the 2012 interviews was weaker for educational research faculty than for the other two types, we would expect to observe activities that are motivating and engaging for students.

There also were some differences in teaching practices among faculty types suggested by the 2012 interviews. For example, teaching faculty in the 2012 REA interviews were more likely than others to talk about course activities that: built on what students already know, were appropriate for a variety of students, included learning assessments, and involved synthesizing ideas from multiple sources of information.

Methods

Target Sample

For participants in the initial case study pilot, we sought to acquire a single case for each of the three types of geosciences faculty: education faculty (focused on education scholarship), research faculty (focused on basic research), and teaching faculty (focused on teaching only). We are focusing on undergraduate geoscience classes. Six possible cases from the interview study were targeted for recruitment first. The classroom observations and review of artifacts are being conducted to confirm and enhance our understanding of the self-reports for these particular interview participants.

Recruiting participants for the three case studies has been difficult and continues at the time of this report. Original plans for recruitment involved targeting the strongest cases from the 2012 REA interviews, but the many refusals from potential participants has made it necessary to expand the search pool several times.

Measures

Syllabus, Course Material, and Strong Teaching Activity Review

REA will request participants' course syllabi and examples of what they consider a strong classroom activity from their course. The course syllabi and/or course materials will be analyzed for the variety and quantity of activities available for students (i.e., lectures, labs, student-centered activities, etc.).

We will also request that faculty share with us any examples of course materials, including previous syllabi that they may have used in their teaching before participating in a CE workshop. These could serve as a baseline for comparing teaching artifacts from before and after CE. Instructors may be reluctant to share their materials, so it may be that they at least have them to inform their discussion with us of what their teaching practices were like prior to CE involvement.

The activity chosen by each case study participant can be analyzed using a lesson plan analysis template adapted from an existing instrument[2] This instrument was adapted to align with the Features of a Strong Teaching Activity promoted by CE. The adapted tool, which is found in Appendix C, consists of 26 desired characteristics of a classroom learning environment. These characteristics are rated with a 1 (Needs improvement), 2 (Making progress), 3 (Exemplary), or NA (Not able to determine). If written descriptions of the lesson are unavailable or more information is needed, we will ask the faculty member follow-up questions to provide clarification. Information about each of the features of a strong teaching activity are incorporated into the template to adapt its use for this project. For example, we will determine if there is behavioral evidence of:

- Clearly stated learning goals
- Learning activity and assessment alignment with the learning goals
- Student engagement in reflection and problem solving
- Student engagement in data collection & analysis, observation, and experimentation
- Building on what students already know and addressing of their preconceptions

Classroom Observations

We will coordinate with participating faculty to identify a date and time for the classroom observation of a lesson that best demonstrates what the instructor has self-identified as a strong teaching activity. Faculty members will be informally interviewed after the course to discuss what CE principles they applied during class and to determine the extent to which they felt students

[2] Jacobs, C. L., Martin, S. N., & Otieno, T. C. (2008). A Science Lesson Plan Analysis Instrument for Formative and Summative Program Evaluation of a Teacher Education Program. Science Education, 92(6), 1096-1126.

were engaged with the activity. To enrich our gathering of observation data, we will use the SLPAI, which is also being used to analyze the lesson plan.

To complement REA observation data, we will acquire through the CE team data from a single classroom observation conducted by a trained RTOP observers for each of our case study participants. These RTOP observations will occur on a date other than the REA observation, and the RTOP observer, not REA or the instructor, will decide the particular date. Thus, we will have RTOP observation data from a random classroom lesson to compare with REA collected data from a date designated by the instructor to be representative of a strong teaching activity. RTOP observations also include the administration of the Geosciences Teaching Practice Survey, so that data could be available along with the observation data.

Faculty Interviews

As needed, brief interviews via phone or email will be used to gather details about learning activities/lessons and information about the course that is unavailable in the syllabi and course materials. This can help us understand their syllabus and materials for the course and fill in gaps that might not be represented in those documents. At the time of the site visit, we can seek further information from faculty about the course and the classroom session.

Findings from Case 1

This section describes findings for the first case study participant. The individual was part of the 2012 REA interviews, and so that data source is integrated into these findings. Our case provides an example of someone who has appeared to shift from being classified as a science research faculty member to an educational research faculty member. He has incorporated a number of new, student-centered teaching practices since his initial involvement in the program; continues to actively develop his competence as a teacher; and continues to design and redesign his courses for undergraduate and graduate students.

Background

Case 1 is a repeat participant of CE workshops. This associate professor of geography attended three workshops and then recently was a co-presenter at a fourth workshop. He began the program seven years ago by attending the early career workshop when he was just beginning his career in academia at a large, public research university. Thus, he also fit into what has been categorized as the early career pathway, and served as an example of someone who teaches at an R1 institution, which is another subset of CE participants.

A couple of years later, he attended his second workshop, which was again focused on career development, with strategic persuasion as its focus. The third workshop that he attended was a content-focused workshop that was centered on energy, titled Teaching About Energy in Geoscience Courses: Current Research and Pedagogy. In 2011, he helped present at a workshop that was an updated version of the second career development workshop he had attended several years earlier.

Reports of Teaching Practices and CE Influence

The faculty member believes he would be a lot less effective teacher if he had not been involved in the CE program. Over the years, he has found that there are very few opportunities outside of CE to develop one's knowledge and skills about teaching, especially a lack of professional development focused in the geosciences. In general, he also finds that there is little support to develop one's teaching. Having CE workshops focused in the geosciences makes them much more efficient for his professional development needs. His CE participation has reportedly given him much more diverse approaches to teaching, has expanded his frame of reference in teaching, and has greatly increased his confidence as an educator.

> *So I would say that as a consequence I'm a much better teacher for it. I'm much more diverse in terms of the way that I deliver material and I feel I guess lot more confident that the approach that I'm doing is a good approach as opposed to not necessarily knowing if the approach that I'm doing is even normal I guess. I have a frame of reference to put my teaching in because before it'd be pretty much an isolated endeavor.*

Given the nature of geosciences education, he finds that he has to create courses "from scratch", and CE has been instrumental in providing him ideas on how to teach about certain topics and how to organize courses in these areas:

> *You have to basically create a lot of courses from scratch...[so] it oftentimes helps to attend a workshop about such a topic before engaging in teaching on that topic...you get some really good ideas that you might not have thought about on your own…*

One example of a new course that he had to develop was an upper-level course about environmental problems. It is focused on helping students correct misconceptions and develop understanding of the Earth as a system. The aim for this course is to provide students more accurate frameworks for understanding environmental issues and problems. He would like to develop their ability to critically evaluate scientific issues in daily life and provide them "tools" to assess the scientific credibility of information they come across. He also wants to provide students with basic understanding of scientific approaches to these complex issues, and to help them develop competence beliefs that they can do science.

One of the techniques he uses to develop these competencies includes relating topics to current events and to other things that students already have some understanding about. He likes to elicit commonly held misconceptions and then directly address their falsehood. He finds that he is able to get students' attention with this approach and get them engaged. The course is for approximately 50 students. Although it is a lecture-based course with no labs or small sections, his approach is to try to make it "lab-like or section-like". This instructor described many different methods for engaging his students and for trying to reach students with “different learning styles”, including:

- Uses clickers in large, lecture-based courses
- Well-defined syllabus of material to be covered
- Questions and other participatory activities in lecture-based course, including having students act out something or doing physical demonstrations of concepts
- Peer-teaching activities involving a problem or question
- Web-based activities as homework or lab assignments where he is able to get formative feedback—the students answer a set of questions related to lecture material
- Students get an outline for each class
- Assessment involves exams, assignments, and projects that include peer feedback
- Multiple methods for teaching to reach students with different learning styles—tries to be flexible in his teaching

Alignment between Evaluation Methodologies

The review of the participant’s CV allowed us to compare and contrast what we learned through interview data. Below is a bulleted list of findings from the review of the CV contextualized in findings from the interview analysis.

- 2005 early career workshop attendee, had started as Asst Prof in 2003. This was also determined through interview.
- 2006 began additional appointment as Geological Scientist Faculty for major research laboratory affiliated with the university, which presumably led to his involvement in informal STEM education.
- He has had a number of other appointments in addition to his primary faculty appointment (has been Associate Prof since 2009).
- CV shows multiple publications in science research in last 2 years. He indicated that he was an active science researcher in his interview.
- CV notes 35 presentations since 1997—according to the interview data, these would be for science research.
- CV confirms self-report in interview of education related activities. No strong record of education presentations. He is listed as a Co-PI on a new education grant, one that was awarded after the interview occurred. No education-related grants had been identified through the interview.
- In addition, he is currently in a high-profile teaching and career development fellows program at his institution for the present school year (2012-2013). This was not identified through the interview, which had taken place in July 2012, prior to application and notification of award. The fellowship involves a year-long series of workshops and seminars on teaching and learning.
- CV lists teaching talks that he has attended or helped facilitate, the same ones that were identified through the interview.
- CV confirms that he has not published about teaching or learning.
- A CV analysis will likely not readily point to correspondence with other faculty about coursework; however, this CV shows that he periodically team teaches with other faculty members, so this may involve some collaboration about the way the course is structured and taught.

- After his initial CE involvement in an early career workshop, according to program records, he attended the workshop, Career Development: Strategic Persuasion, in 2008. He also attended the Teaching About Energy in Geoscience Courses: Current Research and Pedagogy, in 2009 (confirmed in his CV), and he was a co-facilitator at a recent early career development workshop for CE (also confirmed in his CV).
- Through examining his CV, we see that the various education-related activities that he has been involved with appear to have largely begun in the last several years. This shift may be due in large part to the fact that he became an Associate Professor in 2009, which may have signaled the opportunity to focus more on his career enhancement as an educator given that his science research was well-established.
- Through the interview, we learned that CE made him aware of different cognitive strategies for teaching and learning, and that encouraged him to seek out and take advantage of other education activities. For example, it led him to get involved in projects involving a public science center and teaching about ocean sciences, and he has been involved in advisory activities, which leads to analytic and consulting efforts on education research projects at the university. He indicated at the time that he now reads education-related journal articles.

Interestingly, this faculty member was recruited as an example of a “science researcher” (based on his interview responses in July 2012), but a recently completed analysis of 2012 GTP survey data, which was gathered late in 2012, suggested that his faculty type was “educational researcher”. Both the CV and interview data pointed to ways that the case participant has been involved in geoscience education for K-12 and in informal learning settings. In reviewing his CV, it became clear that he became involved in a number of new educational activities since the interview. Thus, further education scholarship was shown in the CV because those activities had occurred after the interview data had been gathered. These additional activities perhaps influenced his classification as an educational researcher based on his survey responses; otherwise, he likely would have been categorized as a science researcher. Therefore, while linkages can be found in the two research methods, the timing of data gathering complicates analysis and interpretation.

Another difference that was surprising involved his teaching style classification. The interview data was interpreted as suggesting his style was “active learning”, while the 2012 survey data classified his style as “active lecture”.

It was found through the interview that his teaching touched on at least seven of the fifteen features that CE has identified as characterizing strong teaching. Table 5 shows where there was some evidence that the case participant for the various teaching strategies. This provides an indication of how evidence from the interview and case study observation aligned and varied.

Table 5. Comparison of Evidence by Method: Features of Strong Teaching

Features of a Strong Teaching Activity	**Interview evidence (from 2012 REA interview)**	**Classroom observation evidence (in large, introductory course to environmental science)**
1. Clearly stated learning goals	Yes	Observed learning goals stated on opening slide for class presentation. Syllabus did not provide goals for course.
2. Activities and assessment aligned with intended goal of the activity	Yes	Activities were aligned with goals but assessment was limited to formative activities involving the professor calling out for answers and doing the think-pair-share.
3. Activity motivates and engages students; encourages student interest and attention	Yes	Uses a lot of visuals on the overhead slides and provides real-world examples to help students understand concepts and their importance. Intersperses humor during class. Placed interactive activities after 20 minutes of lecture. Group problem solving activity was fun and engaging. The think-pair-share activity got all students discussing with one another what they had learned about 3 key topics that were identified by the instructor. The majority of the class was visibly attentive to what was being said and presented on the slides. Many students appeared to be taking notes throughout the lecture about each slide.
4. Activity builds on what students already know and addresses their preconceptions		There were a couple of references by the instructor to what common conceptions were about the topic being discussed. The topic of the prior class session fed into the topic for the observed session, and the instructor actually made some of that connection explicit by recapping a few points from where they left off previously and by finishing up the remainder of the lecture that he had shared in the prior session.
5. Activity is appropriate for a variety of students		
6. Activity engages students in independent thinking, reflection, and problem solving	Yes	The only clear example of this activity is when all students were required to do a think-pair-share. This activity involved

Features of a Strong Teaching Activity	Interview evidence (from 2012 REA interview)	Classroom observation evidence (in large, introductory course to environmental science)
		them reflecting on what they knew about 3 topics that were identified by the instructor. T
7. Activity provides opportunities for students to improve their understanding incrementally	Yes	The lecture did appear to be ordered so that concepts were built upon one another incrementally.
8. Activity has appropriate balance of guidance and exploration		
9. Activity encourages discussion/collaboration	Yes	Questions by the instructor during the lecture components and during the group activity encouraged some discussion between responding students and the teacher. The think-pair-share activity, which lasted only a couple of minutes at the end of the hour-long class, involved peer discussion among pairs and then whole group/class sharing.
10. Activity has places for students to assess their own learning	Yes	The think-pair-share activity was an opportunity for students to assess what they knew and compare that to their peers.
11. Activity contains tips for other teachers	--	(not applicable)
12. Activity engages students in data collection & analysis, observation, and experimentation	--	--
13. Activity helps students visualize data relationships, geologic processes, or their relationships	--	There were numerous examples of visualizations of data relationships, geologic processes, and their relationships. These were depicted for multiple topics during the lecture components.
14. Activity requires students to integrate and synthesize ideas from different sources/experiences	--	--
15. Activity contains accurate scientific information	--	Because the instructor was dealing with rapidly changing climate, he had to explain current data when it was not depicted in his slides.

The GTP 2012 survey data indicated that the teaching style for Case 1 was best characterized as active lecture. See Table 6 below for evidence of teaching style gathered from the interview and from the REA classroom observation. This latter data suggests the faculty member's teaching style would be better characterized as active learning.

Table 6. Comparison of Evidence by Method: Teaching Style

	Teaching Style *1 (Never), 2 (Once), 3 (Several Times), 4 (Weekly), and 5 (Every Class)*	**Interview evidence**	**Case study observation evidence** (large, intro course to environmental science)
Traditional Lecture	a. Traditional lecture	--	--
Active Lecture	b. Lecture with demonstration	He described doing physical demonstrations and sometimes having students act something out.	--
	c. Lecture in which questions posed by the instructor are answered by individual students	--	This was the format for most of the class during the observation.
	d. Lecture in which questions posed by the instructor are answered simultaneously buy the entire class	Description of clicker use during lectures suggested all students would provide feedback.	Clickers were not used during the observation. (see below)
Active Learning	e. Small group discussion or think-pair-share	He described using think-pair-share and peer teaching activities.	The think-pair-share activity required all students to think and describe their answers to their neighbor.
	f. Whole class discussions	--	To an extent, this occurred when there was whole group sharing after the think-pair-share and during the group activity.
	g. In-class exercises	He described using participatory exercises	There was the whole group activity that involved naming gases in the atmosphere, but no hands-on exercise.

An additional source of data about the case participant was available from an observation conducted using the RTOP. The RTOP was carried out for the same undergraduate course just several weeks after the REA interview was conducted. Scoring on the RTOP, as noted earlier, involves a 0 to 4 rating scale, from 'not observed' to 'very descriptive', and includes space for comments.

The total score for the overall RTOP was 68 out of a possible maximum of 100 points. The subscale with the highest average rating (3.6) involved items about propositional knowledge. Example items that received a rating of '4' were, "*The teacher had a solid grasp of the subject matter content inherent in the lesson*" and "*The lesson promoted strongly coherent conceptual understanding*". The observer noted that the instructor used a variety of visual and other strategies to illustrate concepts. These techniques and focus on conceptual learning were also characteristic of the REA classroom observation.

The subscale with the lowest average rating (1.8) involved the items about procedural knowledge. An example of an item with a rating of '1' for this case was, "*Students used a variety of means (models; drawings' graphs; symbols; concrete materials; manipulatives; etc.) to represent phenomena*". This difference in ratings would be expected based on the learning objectives for the course. That is, the 100-level course is focused more on conceptual knowledge rather than procedural knowledge. The observer goes on to explain that there was an opportunity for students to reflect on the accuracy of their prior knowledge through a think-pair-share activity that was conducted during the first 15 minutes of class. During the REA-conducted observation session, a briefer think-pair-share activity was used as a check for learning at the end of the lesson. During the RTOP session, there was no other interactive student activity besides questions and answers during the lecturing. For the REA-observed session, there was an additional activity involving the whole class.

Next Steps

A mixed methods approach can provide us a more nuanced understanding of program influences and help to raise further research questions. Yet, the goal of seeking alignment or confirmation across the different data collection efforts may fail to take full advantage of a mixed method approach. In order to understand how CE is working, for whom, and under what conditions, researchers must complement the correlations found in large-scale surveys with micro-genetic analyses that are only possible with a small sample. As noted before, discrepancies between data sources should not necessarily privilege one source of information over another (i.e., framing the task of the interviews to confirm the survey results), but rather be used to generate new hypotheses about the function of the entire system, defined here as the CE theory of change model.

To date, comparisons of interviews and surveys show a high degree of convergence on impacts, but do not identify a compelling description of or explanation for the pathway from CE participation to faculty outcomes. The hypothesis that pathways varied by faculty type did not take into consideration that type may be a dynamic, not static, quality that varies over time, or that a faculty member could self-identify as one type without demonstrating many or most of the indicators designated for that type in the GTP survey analyses. How then might knowledge be expanded about the benefits of CE participation for students and the factors that mediate the transition from activities to impacts? Are there other units of analyses (e.g., departmental vs. individual) that should be explored? Are there iterative changes over time or even additional outcomes that could be explored in greater depth? Here, we describe several possible activities to pursue as the external evaluation of On The Cutting Edge continues.

Case Studies of Teaching Practices

A next step in the external evaluation of CE can involve conducting case studies of faculty representing additional pathways or subsets of CE participants. Increasing the number of cases could foster understanding of the effects of participation in a single workshop versus multiple workshops, include faculty with different years of teaching experience, and allow for the involvement of several CE participants coming from the same department to examine influences on their academic department. We could seek to compare individuals who first become involved in CE through an early career workshop—like the case described above—with individuals who begin in other types of workshops (e.g., an emerging theme workshop). We might also explore the experiences of an entire department as a contrast to a study of individuals, since the process of group-level change and the role of CE may be quite different from a single individual's journey. We should explore new recruitment strategies to increase effectiveness and efficiencies to conserve project resources. We will also need to expand the pool of potential recruits as we continue to search for faculty who are willing to participate. The burden of participation is perceived to be substantial and possibly interfering with other demand of teaching and research. If this evaluation activity continues in future semesters, we may be able to go back and recruit faculty who had indicated their future willingness to participate, but for various reasons were unable to participate in winter/spring 2013. A modest honorarium may help induce participation, just as a way of acknowledging their trade-offs.

Pathways Interviews

Another potential evaluation activity can involve revising the 2012 interview protocol and then recruiting from a sample of respondents to the recent 2012 GTP survey. Our protocol could be restructured to gather data that more closely aligns with the survey and/or the case study approach. The recruitment sample could just involve workshop attendees who have not previously participated in an interview for CE program evaluation. In addition, the sample could be restricted to individuals who have their faculty type and teaching style identified through the survey analysis. To further the investigation of pathways, we would again seek representation of science research faculty, educational research faculty, and teaching faculty. It would also be important that the workshop participation patterns of the recruitment sample represent a range of the different faculty workshop types and dosage amounts. We could also use strategies such as the Critical Incident

Technique (Fivars and Fitzpatrick, 2006) to track faculty members' growth as educators over time and the key activities, events or social connections that may have influenced that development. The revised interview protocol could be incorporated into the case studies, also.

Social Network Analysis

In past CE interview studies, faculty have reported having multiple career networks. Faculty have explained how they have a network of research colleagues and a network of colleagues with whom they discuss teaching and learning, and some have explained that those networks overlap. As an alternative method to the activities proposed above, an analysis of social networks among geoscience faculty may provide a strategy for gathering new insights into effects of CE participation. We could investigate if the networks have mixed characteristics for different groups of faculty. Past survey findings have shown there to be a greater likelihood for collaboration among educational research faculty. We might seek to determine if that trend appears in other sources of data and see if we can gather information about why that might be the case. For a study of social networks, there would be a variety of topics to possibly address with faculty, for example:

- Who they stay in touch with after workshops
- Who they turn to for information about different topics
- Number of connections
- Number of new connections
- Value of connections: self-report and frequency of interactions
- Collaboration: co-authorship and joint projects
- Reflections about network/community

We could explore the feasibility of developing visual maps of their networks, which can be useful for analysis as well as for providing a framework to guide conversations with faculty. A cross-sectional study could examine faculty networks among CE participants and non-CE participants. A longitudinal study could build off the cross-sectional study by following up with the participants in the first study to investigate possible changes in their networks, perhaps over the course of a year. It may even be feasible to gather baseline data about faculty members' networks prior to their initial workshop participation.

Evaluation Timeline

The current estimated timeline for REA conducted activities is provided in Table 7.

Table 7. Overall Evaluation Timeline

	1 (Mar ‘11-Feb ‘12)				2 (Mar ‘12–Feb ’13)				3 (Mar ‘13-Feb ’14)				4 (Mar ’14-Feb ’15)				5 (Mar ’15-Feb ’16)			
	Sp	*Su*	*F*	*W*	*Sp*	*Su*	*F*	*W*	*Sp*	*Su*	*F*	*W*	*Sp*	*Su*	*F*	*W*	*Sp*	*Su*	*F*	*W*
Determine info needed for pathways analysis	■					■	■		■				■				■			
Collect & report interviews				■		■			■				■				■			
Analyze old interviews								■												
Evaluate pre/post "strong activity" question				■																
Recruit case study participants; collect syllabi, lesson plans, conduct site visit								■			■				■					
Analyze syllabi, lesson plans, and observation data								■				■				■				
Write yearly report	■				■			■					■				■			
Write final summative report																			■	■

Appendix

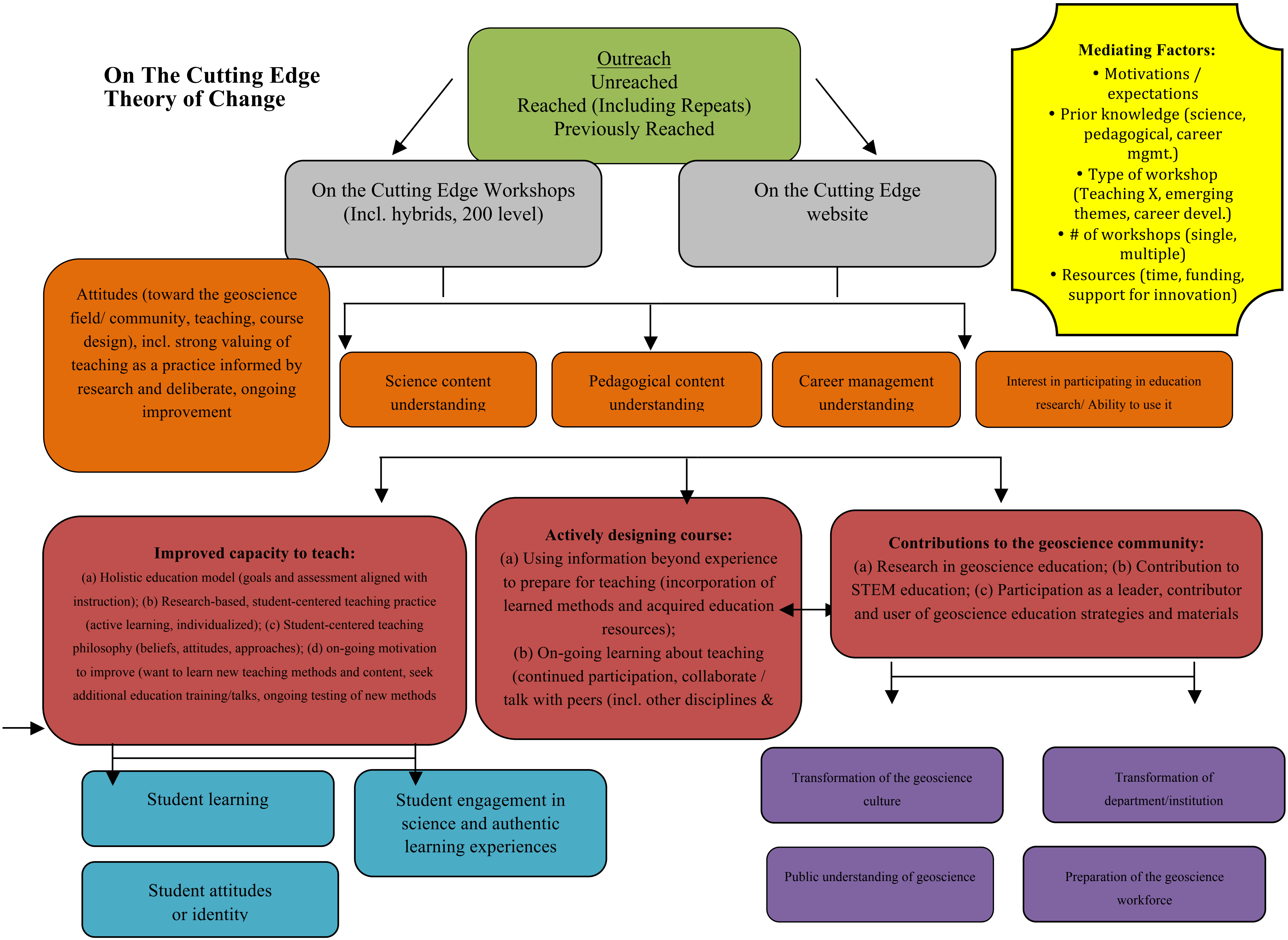
Theory of Change Model

Interim Report on 2012 Follow-up Interviews

2012 Interview Protocol

Appendix A: Theory of Change Model

On The Cutting Edge Theory of Change



Appendix B: 2012 REA Interviews

INTERIM REPORT ON 2012 FOLLOW-UP INTERVIEWS

Purposes

This report contains a preliminary review and thematic analysis of the 20 interviews conducted through August 2012 for the On the Cutting Edge (CE) program, and will inform the development of a confirmatory, comparative case study of CE alumni teaching practices. The program offers a menu of workshops and web-based resources designed to serve the professional development needs of undergraduate faculty teaching in the geosciences. The On the Cutting Edge program is currently focused on three goals for improvement of its efforts to support the needs of the geosciences education community:

1. Expanding the number of faculty who participate in a On the Cutting Edge workshop to 50% or more of U.S. geoscience faculty.

2. Providing advanced opportunities for engagement with the program that encourage repeated participation, enable ongoing learning, and result in increased changes in teaching practice.

3. Improving the website with expanded resources that are created and reviewed by the geosciences community, and by improving the methods for finding materials through the website.

There are two major portions to the theory of change model for the CE program—one concerning implementation of CE and the other concerning program impacts. Expected impacts are viewed in terms of proximal outcomes and more distal outcomes. The proximal impacts involve, for example, what is expected or aimed for through each CE workshop. These intended impacts include:

a. Greater understanding and valuing of educational research

b. Increased knowledge about geoscience pedagogy

c. More positive attitudes toward the geoscience teaching and geoscience community

d. Increased knowledge about career management strategies

A variety of longer-term outcomes are expected to result from CE participation. For instance, distal impacts of CE are expected on instructors' adopted philosophy of teaching and actual teaching practices. In turn, these changes in teaching philosophy and practices are expected to improve students' engagement in science, their attitudes about science, and their learning about science. Another area of distal impacts involves faculty enhancing their efficacy about themselves as geoscientists and geoscience educators. That is, faculty who can effectively conduct research on geoscience and education, who view themselves as leaders in the geoscience community, and active consumers and developers of innovative pedagogical methods for the geosciences.

A major goal of the current interview study was to develop further understanding about the changes that occur among faculty after participating in CE workshops and what influences the program and the CE community network had on those changes. A related goal was to investigate the differences and commonalities among different faculty pathways. We sought to understand how the sample falls along these pathways; what influence CE participation had on each pathway, including variations within pathways; and whether more data is needed for any of the pathways.

The types of pathways include geoscience research faculty, educational research faculty, teaching faculty, and (cutting across these pathways) early career faculty. We also sought to learn about the experiences and practices of both faculty who attended multiple CE workshops and those who attended only one. Geoscience research faculty possess strong science content expertise, but may or may not possess strong pedagogical knowledge. These faculty tend to work at R1 institutions. Educational researchers conduct some science research, but also pay substantial attention to their teaching development and effectiveness. Teaching faculty are characterized as having limited use of CE workshops, website, and network. A related mediating factor that we investigated was whether faculty attended a single CE workshop or several. We also wanted to understand how CE influenced participants at different stages of their academic career, with particular interest in early career faculty. These faculty tend to begin their CE involvement in the early career workshop or other career development workshops.

In examining different pathways of involvement with CE, there has been interest in examining a set of factors that are thought to perhaps mediate faculty participation. These mediating factors are depicted in the top right of the CE theory of change model (see Figure 1). These factors are thought to include motivations for and expectations about taking a CE workshop, gaps in prior knowledge about science content or pedagogical methods, the different types of workshops that faculty attend, and the number of workshops they attend (e.g., single dose vs. repeated dose).

Key research questions for the present study were:

- Are there key differences in how faculty types go through the CE pathways, experiencing different CE outcomes?
- In what ways does a shift to a student-centered teaching philosophy impact teaching practice and student learning? Are there tangible shifts in faculty behaviors such as teaching methods and use of effective assessments across multiple courses, as well as improvements in student learning? To what extent do faculty beliefs and attitudes reflect a student-centered teaching philosophy (i.e., CE “Features of a strong teaching activity”, see below)?
- What impact does repeated participation in CE workshops have on teaching practices? For example, do faculty, who report being supported by CE over time, increase their range of student-centered approaches and quality of implementation?

- To what extent do participants cite their involvement in the CE community as a key reason for their access to new teaching ideas and motivation for changing their teaching?
- Do faculty engage in ongoing revision of their courses and learning about how to improve their approach to instruction and assessment?
- What evidence is there of CE increasing or maintaining faculty contributions to the geoscience community through research, leadership, and contribution to and use of geoscience education pedagogy?

The On the Cutting Edge program has identified key features that are viewed as emblematic of a strong teaching activity in geosciences education (see Figure 2). These features to an extent are embedded in the program as cross-cutting themes, contained in most if not all CE workshops. The themes include metacognition, the alignment of course goals with assessment practices, alignment of course objectives with instructional class activities, use of visualizations, understanding the role of motivation, teaching to the whole student, use of controversial topics in classroom activities.

We used these optimal features of quality teaching to identify themes within the present interview data. We looked for instances of these features *throughout* each instructors' self-reported teaching practices, rather than in reference to a particular teaching activity or lesson.

Figure 2. **Features of a Strong Teaching Activity**

1. Clearly stated learning goals
2. Activities and assessment aligned with intended goal of the activity
3. Activity motivates and engages students; encourages student interest and attention
4. Activity builds on what students already know and addresses their preconceptions
5. Activity is appropriate for a variety of students
6. Activity engages students in independent thinking, reflection, and problem solving
7. Activity provides opportunities for students to improve their understanding incrementally
8. Activity has appropriate balance of guidance and exploration
9. Activity encourages discussion/collaboration
10. Activity has places for students to assess their own learning
11. Activity contains tips for other teachers
12. Activity engages students in data collection & analysis, observation, and experimentation
13. Activity helps students visualize data relationships, geologic processes, or their relationships
14. Activity requires students to integrate and synthesize ideas from different sources/experiences
15. Activity contains accurate scientific information

Findings

In this section, findings and themes from the interviews with past CE participants are first examined along different pathways for the strength of the evidence provided. Here, CE outcomes are defined as the features of a strong teaching activity (see Figure 2). Next, several case narratives are also presented for different pathways and to provide more in-depth description of particular cases to complement the summary of themes for the faculty type subgroups. Finally, the overall faculty interview sample is explored under individual subheadings that largely follow key impact areas depicted in the CE theory of change.

Participants

Twenty faculty alumni of CE were interviewed in total. Interviews were conducted in February-March and July-August of 2012. We attempted to recruit faculty across a range of institution types, at different career stages, and different levels of workshop participation.

Key characteristics of the faculty members that participated in the interviews are presented in Table 2, and a detailed breakdown by each individual is provided in Table 6 in the Appendix with some additional demographic information. Slightly over half of the interviewees (60%) had participated in more than one workshop. The overall average number of sessions attended was two, while the average number among repeat participants was three, ranging from two to five workshops. Some interviewees (25%) also had helped to present at one or more CE workshops. Interestingly, interviewees did not tend to speak about being a presenter, and instead appeared to view themselves as a participant, regardless of the roles that they may have had in helping to deliver the workshops. This was even true of the two interviewees that had a presenter role in all three workshops that they attended. The faculty members who had presented began CE either in an early career or an emerging themes workshop.

A few patterns appeared among groups of interviewees that began their CE involvement at the same type of workshop. The interviewees that began their CE participation at workshops involving emerging themes tended to be senior-level faculty (four of five interviewees), which was defined as having 16 or more years of teaching experience. All three interviewees that began their CE participation at a workshop dealing with a core geoscience topic were faculty members at liberal arts institutions. Six of the nine interview participants that started their CE involvement with the early career workshop or career preparation workshop came from research institutions. These different starting points for CE participation have contributed to the thinking about the pathways characteristic of groups of geoscience educators who participate. Some of the findings from the interviews are framed by a consideration of these pathways.

***Table 2*. Faculty Types and Workshop Attendance**

First workshop type	n	Workshop repeater	Average number of workshops *	Workshop attendance range	Served as a workshop presenter	Institution type (at time of 1st workshop)	Faculty type
Early career	7	5	2	1-4	2	5 research 1 private 1 comp.	5 Geoscience Researcher 2 Educational Researcher
Career prep	2	1	2	1-3	0	1 research 1 other	1 Geoscience 1 Educational Researcher
Course design	3	1	1	1-2	0	2 research 1 public	2 Geoscience Researcher 1 Teaching Faculty
Emerging themes	5	5	4	3-5	3	2 research 2 comp. 1 2-year	1 Geoscience 1 Teaching Faculty 3 Educational Researcher
Core geoscience topics	3	0	1	1	0	1 public 2 private	3 Teaching Faculty

* *Attendance up to 2/2012*

Two of the interviewees only recalled and discussed their participation in a SERC (non-CE) workshop. They did not report about their experience in a CE workshop or about its impact. There were two interviewees for whom we did not have an interview transcript for—one had requested to not be recorded (the one who did not remember her CE workshop), and there were significant problems with the audio quality for the other interview.

Investigating Impacts By Faculty Pathway

Alignment of Instructors' Reported Changes with CE Features of a Strong Teaching Activity

The techniques or approaches identified by each faculty member were coded and aligned with the CE features of a strong teaching activity (see Table 3 and a breakdown for each individual in Table 7 in the Appendix). There was no to limited evidence for most of the features (10 of 15), with "limited" = 0-6 cases, "intermediate" = 7-13 cases, and "strong" = 14-20 cases.

Table 3. **Evidence of Student-Centered Teaching Practices for Geoscience Faculty Overall**

Teaching Features	**Level of Evidence**
1. Clearly stated learning goals	Limited
2. Activities and assessment aligned with intended goal of the activity	Limited
3. Activity motivates and engages students; encourages student interest and attention	Strong
4. Activity builds on what students already know and addresses their preconceptions	Limited
5. Activity is appropriate for a variety of students	Limited
6. Activity engages students in independent thinking, reflection, and problem solving	Strong
7. Activity provides opportunities for students to improve their understanding incrementally	Limited
8. Activity has appropriate balance of guidance and exploration	Limited
9. Activity encourages discussion/collaboration	Strong
10. Activity has places for students to assess their own learning	Limited
11. Activity contains tips for other teachers	Limited
12. Activity engages students in data collection & analysis, observation, and experimentation	Intermediate
13. Activity helps students visualize data relationships, geologic processes, or their relationships	Intermediate
14. Activity requires students to integrate and synthesize ideas from different sources/experiences	Limited
15. Activity contains accurate scientific information	Limited

** Levels: limited = 0-6 cases, intermediate = 7-13 cases, strong = 14-20 cases.*

There was strong evidence of most instructors being influenced by CE to integrate methods at engaging and motivating students (feature 3); for providing activities that encouraged students to think critically and reflect and to solve challenging problems (feature 6); and for providing opportunities for students to collaborate and discuss with each other and the instructor (feature 9). For each faculty type (geoscience researcher, educational researcher, and teaching faculty), there was a similar average number of these teaching features (5, 5, and 6 respectively).

As an example, use of visualizations was a teaching practice that had an intermediate level of evidence of it being integrated into instructors' classrooms. Over half of the interviewees referred to using some type of visualizations in their teaching, such as animations, graphic images of data, or physical models and demonstrations. These visual methods were presented to students to provide them opportunities to ask questions and interpret what they were observing.

The weakest evidence in the faculty interviews (i.e. the features they talked about the least) were activities that included tips for teachers (feature 11), having accurate scientific information (feature 15), and improving student understanding incrementally (feature 7).

The following analysis explores whether there are any patterns between the different faculty types/pathways. Faculty interviews, which had previously been coded for evidence of CE features of a strong teaching activity, were categorized by pathway (see Table 4). Here, "limited" = 0-1/3 cases, "intermediate" = 1/3-2/3 cases, and "strong" = 2/3-all cases.

Table 4*. Evidence of Student-Centered Teaching Practices By Faculty Type

Teaching Features	Research Faculty (N=9)	Educational Researcher (N=6)	Teaching Faculty (N=5)	Early Career** (N=9)
1. Clearly stated learning goals	Limited	Limited	Limited	Intermediate
2. Activities and assessment aligned with intended goal of the activity	Limited	Limited	Limited	Limited
3. Activity motivates and engages students; encourages student interest and attention	Strong	Intermediate	Strong	Strong
4. Activity builds on what students already know and addresses their preconceptions	Limited	Limited	Intermediate	Limited
5. Activity is appropriate for a variety of students	Limited	Limited	Intermediate	Limited
6. Activity engages students in independent thinking, reflection, and problem solving	Strong	Strong	Strong	Strong
7. Activity provides opportunities for students to improve their understanding incrementally	Limited	Limited	Limited	Limited
8. Activity has appropriate balance of guidance and exploration	Limited	Limited	Limited	Limited
9. Activity encourages discussion/collaboration	Strong	Strong	Strong	Strong
10. Activity has places for students to assess their own learning	Limited	Limited	Intermediate	Limited
11. Activity contains tips for other teachers	Limited	Limited	Limited	Limited
12. Activity engages students in data collection & analysis, observation, and experimentation	Limited	Intermediate	Intermediate	Intermediate
13. Activity helps students visualize data relationships, geologic processes, or their relationships	Intermediate	Intermediate	Intermediate	Intermediate
14. Activity requires students to integrate and synthesize ideas from different sources/experiences	Limited	Limited	Intermediate	Limited
15. Activity contains accurate scientific information	Limited	Limited	Limited	Limited

** Levels: limited = 0-1/3 of cases, intermediate = 1/3-2/3 cases, strong = 2/3-all cases.*

*** Note: Early Career faculty were identified by the workshop they first attended. These faculty overlap with the other three categories.*

A few differences were observed among different pathways. For example, Early Career faculty were slightly more likely to talk about clearly stated learning goals (feature 1) than other groups. Teaching faculty were more likely to talk about activities that build on what students know (feature 4), activities being appropriate for a variety of students (feature 5), activities with assessments (feature 10), and activities that synthesize ideas from multiple sources (feature 14) than other groups. Interestingly, geoscience researchers were less likely to talk about activities that engage students in research practices (feature 12). Finally, educational researchers were less likely to discuss activities that motivate and engage students (feature 3).

Case Studies Along Different Pathways
This section provides a series of comparative cases that vary among dimensions such as faculty type, stage of career, workshop dosage, and type of institution.

Case 1 (geoscience researcher, early career, multiple workshops)

The first case study involves a repeat participant of CE workshops. This associate professor of geography attended three workshops and then recently was a co-presenter at a fourth workshop. He began the program seven years ago by attending the early career workshop when he was just beginning his career in academia at a large, public research university. His second workshop was a couple of years later, and it was again focused on career development, with strategic persuasion as its focus. The third workshop that he attended was a content-focused workshop that was centered on energy, titled Teaching About Energy in Geoscience Courses: Current Research and Pedagogy. Recently, he helped present at a workshop that was an updated version of the second career development workshop he had attended.

The faculty member believes he would be a lot less effective teacher if he had not been involved in the CE program. Over the years, he has found that there are very few opportunities outside of CE to develop one's knowledge and skills about teaching, especially a lack of professional development focused in the geosciences. In general, he also finds that there is little support to develop one's teaching. Having CE workshops focused in the geosciences makes them much more efficient for his professional development needs. His CE participation has given him much more diverse approaches to teaching, has expanded his frame of reference in teaching, and has greatly increased his confidence as an educator.

> *"So I would say that as a consequence I'm a much better teacher for it. I'm much more diverse in terms of the way that I deliver material and I feel I guess lot more confident that the approach that I'm doing is a good approach as opposed to not necessarily knowing if the approach that I'm doing is even normal I guess. I have a frame of reference to put my teaching in because before it'd be pretty much an isolated endeavor."*

Given the nature of geosciences education, he finds that he has to create courses "from scratch", and CE has been instrumental in providing him ideas on how to teach about certain topics and how to organize courses in these areas:

> *"you have to basically create a lot of courses from scratch...[so] it oftentimes helps to attend a workshop about such a topic before engaging in teaching on that topic...you get some really good ideas that you might not have thought about on your own about which belongs in a class and approaches..."*

One example of a new course that he had to develop was an upper-level course about environmental problems. It is focused on helping students correct misconceptions and develop understanding of the Earth as a system. The aim for this course is to provide students more accurate frameworks for understanding environmental issues and problems. He would like to develop their ability to critically evaluate scientific issues in daily life and provide them "tools" to assess the scientific credibility of information they come across. He also wants to provide students with basic understanding of scientific approaches to these complex issues, and to help them develop competence beliefs that they can do science.

One of the techniques he uses to develop these competencies includes relating topics to current events and to other things that students already have some understanding about. He likes to elicit commonly held misconceptions and then directly address their falsehood. He finds that he is able to get students' attention with this approach and get them engaged. The course is for approximately 50 students. Although it is a lecture-based course with no labs or small sections, his approach is to try to make it "lab-like or section-like". This instructor described many different methods for engaging his students and for trying to reach students with "different learning styles", including:

- Uses clickers in large, lecture-based courses
- Well-defined syllabus of material to be covered
- Questions and other participatory activities in lecture-based course, including having students act out something or doing physical demonstrations of concepts
- Peer-teaching activities involving a problem or question
- Web-based activities as homework or lab assignments where he is able to get formative feedback--the students answer a set of questions related to lecture material
- Students get an outline for each class
- Assessment involves exams, assignments, and projects that include peer feedback
- Multiple methods for teaching to reach students with different "learning styles"--tries to be flexible in his teaching

This case provides an example of a research faculty member coming from a major R1 university who then went on to develop significant pedagogical expertise and who continues to actively develop his competence as a teacher and continue to design and redesign his courses for undergraduate and graduate students.

Case 2 (Educational researcher, early career, attended one workshop)

The second case is a junior faculty member at a private, liberal arts university. He is an example of an early-career CE pathway participant who attended a single CE workshop. He had only been teaching for about a year prior to his participation in the early career workshop.

In his interview, this CE alumni reported that, "One of the major things the workshop did was it just gave me a whole variety of different resources for I would say in general kind of active learning techniques." CE helped him develop an understanding of why it was important, but also the skills and resources to better integrate the active learning strategies into his teaching. He added, "I think this program really opened my eyes to the importance of kind of engaging the students in the process along the way." Clearly, he developed an awareness and appreciation of a student-centered approach to teaching and learning.

The shifts in attitudes were described to lead to a variety of techniques he used in teaching and assessing learning, including:

- Choice of student presentation topic
- Building off of students' prior conceptions
- Using small group activities, hands-on activities, and problem based learning activities
- Using brainstorming activities
- Teaching quantitative skills and concepts, including incorporating calculations into activities
- Emphasizing the "real world importance of everything" being studied—wanted student appreciation and awareness about this
- Engaging students in an independent research project
- Having students practice lab techniques
- Engaging students in data use activities
- Integrating "low stakes assessment" into his courses—formative assessment and student self-assessment

This faculty member did not think that his experience of CE impacts was unique to his situation, and he said that he "would recommend to anyone in the geo-sciences—however they're connected to the geo-sciences—to take advantage of this opportunity." He strongly felt that at least a portion of his overall career success was due to the early career workshop. After a single dose of a CE workshop, he reported engaging in ongoing learning about teaching and learning, and was engaged in educational scholarship, including publishing and presenting at teaching focused conferences. He wants to attend future CE workshops.

Case 3 (geoscience researcher, senior-level, attended one workshop)

The next targeted case study is an example of a faculty member who reported CE having a major impact on their teaching practices despite having only attended one workshop, which was about course design. Case study 3 also teaches at a large, public research university. She is a full professor in the geology department. When asked to reflect on what her teaching was like before CE and compare it to how she now teaches, this faculty member explained that:

> *"One of the funny things in the teaching profession is you are a graduate student one year, and then you get your Ph.D., and then you become a faculty member and you are suddenly on the other side of the podium and nobody has taught you how to teach; so, many people try to imitate their advisors, which is a deadly mistake, because you are not your advisor…So, I think the basic thing I learned…was how to design a course—not on content basis, not on teacher basis—but student focus, and that made a big difference on me as well as on my students."*

The undergraduate course that she is teaching this fall involves teaching about volcanology to about fifty majors and non-majors. Prior to her participation in the CE workshop, she organized her courses so that students were responsible for demonstrating predominately declarative knowledge. The questions required students to remember facts. After the workshop, she changed to a student-centered approach and emphasized student conceptual understanding and application of learning to new contexts to test transfer. In the volcanology course, she teaches it so that students experience several modeling opportunities of how scientists study a particular volcano, and then they are tasked with independently going through the same process to study a new volcano and then conclude by delivering a presentation to the class. Her evaluation of students' learning and performance in the course is now focused on this latter set of activities rather than on responding correctly to recall questions on tests. She gets students talking in her courses about how they would go about finding answers to certain problems, how they would analyze data, etc. She has them discuss these issues among each other in small groups. Sometimes she splits the class in two and gives each group a different side of a controversial topic (e.g., one side pro, one side con).

This faculty member provides an interesting example of an instructor with many years of teaching experience who nevertheless experienced a major shift in how she thought about and approached the design and teaching of her courses. She also is demonstrative of someone who particularly appears drawn to developing expertise in new, emerging areas of geoscience education. She continues to be on the lookout for future CE workshops that she is able to attend.

Case 4 (educational researcher, senior-level, multiple workshops)

Like the previous case that was just discussed, this next case is another example of a faculty member who first became involved with CE as a senior-level professor. After many years of teaching experience, including many years teaching at a comprehensive university, this professor attended an emerging theme workshop in the program. She subsequently went on to participate in another CE workshop and has attended a series of the program's webinars.

According to this participant, one of the most significant impacts of CE was on her networking opportunities. She found that the workshops made her more enthusiastic about teaching and "gave her energy". At the first workshop several years ago, she developed a course about energy that she successfully went on to implement at her institution. From the field learning workshop, she gained a great amount of ideas and resources to build into and improve her field-based experiences for students. She described how she always gained many new teaching examples and ideas from all the sessions she participated in. In addition, CE also reinforced some of what she was doing already in her classes; yet, her involvement with CE also helped her to be more creative with her teaching. She indicated her appreciation for the overall program and explained, "you have the benefit of meeting with your colleagues face to face, and then afterwards having that information online; and that way you don't feel like once the workshop is over, it is over."

Without these opportunities, she said that would not be able to focus on developing knowledge and skills in a particular area, which she learns during the summer and that carries her throughout the year. Thus, she cited CE as providing her a year's worth of inspiration for teaching, and she looked forward to her summer CE workshops so that she could learn new content areas and innovative teaching and assessment techniques, which she would build into her existing courses or use to develop a new course.

The classroom environments that she described sounded quite dynamic in terms of both instruction and assessment strategies that were used: group learning, including jigsaw activities;

collaborative papers; problem-based learning; field experiences; group assessment paired with individual assessment; blogs, journals, sketching; and learning and assessment activities to get at different modes of learning (e.g., audio-visual).

The offering of workshops during the summer months is key for her participation. Furthermore, she explained that besides the timing of when CE activities were offered, financial constraints were another factor that sometimes limited her ability to travel to participate in workshops that she would otherwise would have likely attended.

Case 5 (teaching faculty, emerging theme, multiple workshops)
The fifth case is a senior faculty member and department chair at a two-year community college. He is an example of a CE pathway participant who attended multiple workshops and later led a workshop of his own.

Participating in CE workshops has inspired this individual to update the content and pedagogy in his courses and to embrace change as an inherent (and welcome) aspect of teaching. He observed that:

> *One of the exciting things about teaching is figuring out new ways to improve student learning. ... I think I'm better prepared to embrace new ideas and evolve with the times by attending the Cutting Edge workshops. I think if I didn't go to any of the workshops I probably would not embrace growth as much or embrace change in the dynamics of the evolving educational environment.*

The most important thing this faculty member says he does as a geoscience educator is to *"to try and motivate students for learning and create an environment that is amenable to learning, helpful for student learning and provide resources that students can access to help them learn."* His approach to one of his current courses demonstrates his ability to encourage student interest and attention through activities that engage students in independent thinking, reflection and problem solving. In the quarter in which he was interviewed, the professor was teaching all hybrid classes which combine online delivery of material with weekly lab sessions. The lab exercises give students direct experience constructing interpretations from their own data:

> *It's mostly a hands-on, doing measurement and inferring information from the measurements. ... It's mostly get to work and they discuss things in their groups. It's small group work, usually groups of three or four students in our laboratory setting.*

This professor also acknowledges that one of the greatest challenges in his teaching is the need to construct activities that can meet the needs of a diverse student audience. In his introductory classes, he sees a wide range of quantitative and communication (i.e., writing skills). Over time, he has been better able to accommodate the variety of student needs with activities and classroom environments that allow all students to be successful. As he observed: *"I have to achieve a balance so that students can learn things but also be successful as they work through."* The CE workshops have kept him updated on the ways in which students learn and made him recognize the value of revisiting his teaching approaches to reach diverse and dynamic student populations.

In some cases, his teaching methods have shifted quite dramatically as a result of his CE participation. He recalled this conversation with a fellow workshop participant:

> *in the quantitative skills workshop I spent a bit of time interactive with a guy from the University of Washington oceanography program who was also interested in teaching students about he carbon cycle. We both had similar activities but we approached them quite differently. After our conversation, both of us realized that we would have to change what our activity looked like to get a better representation of reality and make it more meaningful for students. (…) I finally got it fixed up so it did give a better representation and allowed the students to explore things in a more realistic situation or realistic light.*

In short, this case demonstrates that it is possible to teach an old faculty member new tricks. In his words, years of CE participation *"made me being a geosciences educator a lot more exciting and a lot more rewarding. It helps make my job fun."* His students are the beneficiaries of his renewed engagement, receiving courses that are grounded in the most up-to-date research on geoscience and student learning.

Case 6 (educational researcher, senior-level, multiple workshops, many department colleagues are CE participants)

There was one interviewee that stood out as someone who had multiple members of his department influenced by CE. Including him, at least seven of his twelve-member department also participated in CE workshops over the years. He felt they had great teachers in his dept. because of their participation in CE. They informally share among each other ideas and resources they acquire in workshops:

> *"…if someone goes to a course-specific workshop like when our mineralogist went to the teaching mineralogy, or the petrologist went to the teaching petrology, there's not a lot of cross-sharing that goes on except among the people that they're teaching those courses. If it's a real general one like the visualization or the affective domain, or something, I think the sharing is more informal than formal. And so there will be, like I went to an assessment workshop and so I've been using the, what do they call it, the knowledge surveys that we talked about quite a bit, and other faculty have now adopted some knowledge surveys. So I think it does spread, yes, informally."*

This case might be an interesting one to follow up on and to gather information about his colleagues' experiences with CE and assess changes in teaching practices across the department.

Impacts of CE on Geoscience Faculty Overall

Changes in Faculty Knowledge, Skills, and Attitudes About Teaching

As learned in prior interviews and surveys, faculty tend to attribute many significant changes in their teaching approaches and methods to their workshop participation and website use. Overall, we found evidence in the present interviews that CE participants experience a change in understanding and attitudes about teaching and learning. For many faculty, CE was their first exposure to thinking about pedagogy—even becoming aware of the term 'pedagogy' for the first time. CE workshops were repeatedly credited with increasing participants' knowledge about the nature of learning and its implications to designing more effective learning environments. In these interviews there was repeated evidence of faculty experiencing a shift from teacher-centered to student-centered instruction after their CE involvement. Among faculty who already tried to make their teaching student-centered before CE, there were reports of significant improvements both in the variety and sophistication of teaching techniques and in course design. Student-centered approaches to teaching are closely related to active learning approaches. For example, a large-sized course could be characterized as being student-centered if it involves active learning methods in addition to lecturing. Faculty repeatedly described their teaching after CE as involving active learning techniques designed to get students engaged in learning within and outside the classroom. These techniques included problem-based learning, small group activities, controversial topic activities (e.g., pro and con discussions, brief reporting of issues), open-ended questions, and role playing or other simulation tasks.

Changes in Actively Designing Courses

In addition to gains in attitudes, knowledge, and skills about improved pedagogical practices, faculty also reported (as one faculty member described it) "redefining and reinventing" their courses as a result of CE. Faculty members described a range of strategies they learned through CE to restructure their traditional, lecture-based courses into classrooms that engaged students in the learning process and developed their interests. They learned ways to organize their courses so that they could interact with the students during their lectures, such as asking them questions and breaking them up into pairs or small groups to engage in activities.

One alumnus described how, although the first half of the semester in the small graduate-level courses she taught were characterized by lectures with interactive activity interspersed throughout, in the latter half of the semester, she shifted to having students individually teach the class about a certain subject they had researched or that was their area of specialization. Such activities can encourage students to integrate and synthesize information from a variety of sources and experiences, and they can build on students' interests and help sustain attention in a certain topic area to deepen their understanding. A majority of our interview participants explained that they had found more ways to have students discuss topics in class as a result of their participation in CE.

One alumnus had this to say:

> *"The influence of Cutting Edge was practically massive on my teaching. When I walked into my first classroom prior to Cutting Edge all I knew about was standing up there and lecturing to the students. I would stand there and I would just lecture for an hour or whatever. Cutting Edge very much introduced me to a lot of active and collaborative learning techniques."*

He went on to describe how he came to realize that he could pause during a lecture and then have students collaborate with each other using methods such as think-pair-share. He also learned to restructure his course so that he aimed to teach less content overall, but to teach it better.

Impacts of CE participation on teaching practices included teachers' new approaches to assessment in their courses. Many faculty members explained how their experience with assessment as an undergraduate student typically involved just a couple of examinations. The new pedagogical knowledge they gained from the workshops suggested new ways to think about the purposes of assessment (e.g., formative versus summative, offering multiple modes of assessment to embrace multiple learning styles) and new methods for evaluating what students' know and can do. For instance, the notion of "real-time assessment" was described as previously unknown to a particular CE alumnus. After her CE involvement, however, she began having students use response clickers to provide immediate feedback during class about everyone's level of understanding. At the end of classes, she now tends to have students turn in brief assignments; or, for particularly challenging topics, she will have students hand-in or email their perceptions about what the most important topic was. These are concrete ways that active engagement techniques are incorporated into the structure of a course that previously emphasized passive listening to lectures.

In general, many faculty explained that CE led them to use a "multi-pronged approach" when it came to classroom assessment. As an example:

> *"I try to tackle or try to address a different style of learning, so one assignment might be to write a two page paper about this topic. Another might be get on the internet and look at, go to the USGS site and look at all of the earthquakes that have occurred in the last week and look for spatial patterns and another one might be construct a warning poster that you would put around a community that is at potential tsunami risk. We've got five of those; it turns out they come due about every two weeks and they are all different, but in those cases I'm trying to assess the content, through asking them to apply the content in different ways."*
>
> *Early Career Faculty*

CE also impacts participants' teaching practices through the network of colleagues it gives them access to. For junior faculty, attending a CE workshop early in their career gave them exposure to a network of colleagues that many said they would not have been exposed to or would only have come to know later on in their career. Thus, experiencing that expanded network earlier in their career could be advantageous and accelerate their development as a geoscience professor. For instance, in describing what he viewed as the most important benefit of CE workshops, a faculty member explained the value of exposure to his colleagues:

> *"…but its similar to the issue we find when we go to professional meetings; that the reason you go to meetings is to present and listen to research talks, but in fact, the most valuable aspect, or a very valuable aspect is the interactions with colleagues in the hallways, between the talks, and I think somewhat similar about these workshops. They really have been very useful to me, and valuable to the community, but the value is as much in getting people to think about these issues and discuss them amongst their peers as it is proselytizing or producing fundamental changes in the integration of educational research into our teaching techniques."*

Changes in Faculty Science Content Knowledge

Several faculty members described how they have developed or are in the process of developing new courses with content that is new to them. Thus, CE workshops provide faculty tools to not only redesign courses, but also develop new courses in content areas where they previously lacked experience or expertise:

> *"Well, in the geosciences unlike many other sciences, a lot of the courses are not defined historically. You have to basically create a lot of courses from scratch. Whether it comes to teaching climate change or teaching about energy or teaching about environmental issues…it oftentimes helps to attend a workshop about such a topic before engaging in teaching on that topic. This can help structure a class…If you attend a workshop on that you get some really good ideas of things that you might not have thought about on your own."*

In addition, participants are taking leadership roles in developing whole new degree programs. For example, one CE alumnus described how she was leading the creation of a program in sustainability. Another explained that he might not have gone on to be president of a national professional teaching organization if he had not participated in several CE workshops.

As a result of learning about the big ideas in the geosciences (and sciences in general) through their participation in CE, many faculty members have refined and focused the content in courses they teach to focus on the big ideas. This is particularly true for introductory level courses. For example, developing scientifically literate or critical thinkers was a common theme among interviewees.

A recurring theme in the interviews was that CE helped faculty to understand and appreciate a pedagogical approach that emphasized quality over quantity of learning. Before CE, faculty described feeling a need to teach all content covered in the textbook. Particularly in introductory level, survey courses, there is a tremendous amount or range of content to potentially cover. This led some faculty to always feel the need to be highly didactic and thus use a lecture and PowerPoint format in their classes, and to always feel pressured to move through as much content as possible. After participation in CE workshops, faculty learned to slow the pace of their teaching and to teach the same content in multiple ways. They learned ways to get students actively engaged in the content (e.g., student presentations on a particular topic) to stimulate their interests about it and to deepen their understanding of concepts/the big ideas.

Changes in Competence Beliefs

It was highly common in the interviews for faculty to refer to the confidence they gained as a geoscience educator as a result of their CE experience. Faculty members gain a great deal of knowledge about pedagogy in general as well as knowledge about specific strategies for specific (sometimes new science) content and contexts. The gains in pedagogical knowledge foster self-efficacy and empower faculty to more readily access new information, new strategies or methods for teaching and assessing students.

Involvement in Geoscience Education Community

Overall, there was a modest level of increased involvement in accessing educational research and engaging in scholarly work about educational improvements. Several past CE participants have described writing and winning education grant proposals. They attribute this to CE, saying that they would never have even imagined considering this or having the confidence to do so without their CE experience. Some faculty members also described how the things they learned in CE and the confidence they gained as a result of that influenced their becoming involved in education committees at departmental, institutional, regional or national levels.

Increases in pedagogical content knowledge (PCK) gained from CE involvement (which were discussed previously) gave faculty the ability to more easily access and apply teaching methods and materials that were made available on the CE website. This PCK also enabled and stimulated participants' reading of scholarly journals about geosciences education.

Faculty reported bringing back what they have learned in CE workshops and sharing it with their department colleagues and colleagues at their institution overall. Sharing was accomplished through both informal means, such as in departmental meetings or in one-on-one discussions with their colleagues, as well as by more formal means, including workshops and colloquia. There appeared to be some limits as to how many participants could share content-specific approaches to teaching and learning when they were within a geosciences department that had one expert faculty in each domain or area, thus making content sharing irrelevant.

Of course, as noted earlier, about one-fourth of the participants had been involved as co-presenters in CE workshops. Through their teaching roles in CE workshops, these faculty members were able to advance their careers as education scholars, while gaining knowledge from their colleagues who participate in the workshops.

A number of faculty members reported that after attending their initial CE workshop, they began taking advantage of education-focused workshops in other (non-CE) settings. When opportunities for teaching workshops or colloquia were available at their home institution, faculty generally seemed to take advantage of it. The difference, of course, was that these institutional offerings were not focused on the geosciences, which faculty overwhelmingly cite as one of the key advantages of participating in CE workshops and accessing resources on the CE website.

Changes in Career Management

Some interviewees have described their CE experience as life changing. For example: One CE alumnus already had a passion for teaching prior to CE, but she teaches at a very research-focused institution (and department) that does not actively support a teaching focus. She reported that there is no community there of faculty concerned with how they teach and or engaged in sharing ideas on how to improve. Her CE experience, however, exposed her to the geoscience education community and empowered her with resources and a network to rely on. Having these sources for ideas, tools, etc. was viewed as key to balancing her primary role as a geoscience researcher with her desire to always improve her teaching and to try new methods. Without them, she would have to spend too much time with trial-and-error. She still has to test things and make adjustments based on feedback, but is much more efficient because of the CE resources. She remains at the same institution, but would not have if it were not for CE. She now engages in education scholarship and is collaborating with education researchers to investigate some of the CE methods or CE-inspired methods that she uses in her courses.

Not having to "re-invent the wheel" was a common refrain among interviewees. The availability of tested, content-specific resources—including syllabi, assignments, presentations, and demonstrations—helped faculty become more efficient with their time and enable them to take on new teaching assignments. Although, because there are so many resources available through the CE website, some faculty said they found the site overwhelming or difficult to navigate.

Faculty members repeatedly described how their research background and emphasis did not prepare them for student-centered teaching. In fact, they were reportedly unaware of this concept, and most reported having no pedagogical knowledge prior to their involvement. They tended to teach in the traditional, didactic manner that they had experienced. Yet, they reported that their involvement in the CE program expanded their pedagogical knowledge, taught them instructional and assessment methods, and gave them ongoing access to additional methods through the CE website, workshops, and CE network.

Some CE alumni were able to share various examples of taking on leadership roles in geosciences research, teaching, or professional service (e.g., helping to develop and lead sustainability initiatives on campuses or in professional organizations).

Early Career Faculty

Especially for early career faculty, there was a lack of a network of geoscience colleagues that they could rely upon to figure out how to develop and teach courses. They also had the broader concerns and challenges associated with understanding, planning, managing, and evaluating their responsibilities as an academic professor. Faculty who had previously felt isolated from the field of geoscience educators, reported an expansion of their network after participating in CE workshops and gaining ongoing access to new strategies for student-centered teaching in the geosciences.

Early career workshop participants (like the faculty described immediately above) reported learning a great amount about how to balance their multiple roles and responsibilities in terms of research, teaching, and service-related activities. They also reported learning about balancing career and personal life.

Continual Improvement and Innovation of Teaching

Another common thread among faculty was how they are always seeking ways to improve how they approach the courses they teach. Faculty described that they would attend CE workshops or search the CE website both to find out new ways to teach their usual courses as well as to look for ideas on how to take on the challenge of teaching new courses. The teaching changes that faculty sought to make were focused on creating more opportunities for students to actively engage in learning or demonstrate different levels of knowledge and skill.

A majority of interviewees cited a desire to attend additional CE workshops, but considerations of timing, locations, and possession of enough time and/or funds were frequently mentioned as limiting factors. Faculty who straddle multiple fields had less time due to a need to split their professional development time between fields. Yet, for many of these individuals, they were able to rely on the CE website to fuel their need for learning new, alternative methods for teaching.

One faculty member said, "…the website, it's a great resource, and I've also passed that on to others in my position who teach small classes or Master's level students, and they found it great." Others also relied upon colleagues they had met within the CE network to identify new ways to confront teaching issues they faced.

Faculty explained that, through CE, they had learned knowledge, skills, and confidence that helped them to develop and test new ways of approaching instruction and assessment in their courses. For some, a motivation to continually improve their teaching existed prior to CE, while for others that passion tended to emerge after their initial CE experience. It was common for faculty to discuss ways they had developed or were in the process of developing new courses from scratch or otherwise taking on the responsibility of teaching coursework that was new to them.

When asked what were the most valuable benefits of CE participation, a faculty member said:

> *"…the first thing that comes to mind is seeing and experiencing concrete examples of certain methods that were taught in these workshops. It's one thing to just recognize that there is something called the jigsaw or gallery walk and it's another thing to actually see it in practice with some example that you might actually use in your class or an example that's very similar to something you'd use in your class. So, actually going through role-playing some of these exercises was very valuable. I actually used some of them pretty directly in my classes…Those are things that you can enact right away as you get used to new different teaching techniques and then you kind of get the idea and after practicing with that for a while you can kind adapt to other ideas as well."*

Student-Level Impacts

Faculty members commonly describe influences of CE on their teaching practices, but what are the impacts on students? How would things be different for students without these shifts in teaching practices towards more student-centered teaching? There appeared to be several examples of changed teaching practices that were attributed to CE involvement and were likely to have made improvements in course impacts on students.

One example area where changes in teachers' practices appeared to have impacts on students, involved the expansion of opportunities for students to demonstrate learning. This provided students greater flexibility, and as some teachers viewed it, addressed students' different styles or preferences for learning. As mentioned earlier, alumni were able to cite using a variety of ways to assess student learning. Some talked about providing their students ways to earn additional credits or make up points on missed assignments. Although some may view these as common practices, the reality was that many of these faculty members did not teach that way prior to CE.

Another way that CE-influenced changes might have impacted students was by developing large, long-term projects that students could really grapple with a particular content area, investigate and experience why the research is important, reflect on why they chose that area, what its role is in society, and get hands-on experience in using lab techniques. Faculty went beyond their traditional lecture and textbook driven approaches to creating opportunities for students to practice skills, such as writing research proposals or using certain types of computer tools.

Faculty talked about the ways that CE led them to create more challenging assignments and activities that can enable students to "reach the maximum level of productivity". Of course, this is just one example of the many ways that faculty used to increase student engagement in the classroom.

Some other themes that arose in the interviews, which suggested greater student learning, were an emphasis on deeper understanding of concepts and greater focus on conceptual learning overall. A core emphasis in introductory level courses was on students "learning the fundamentals", while in higher-level courses, great attention could be also placed on developing skills.

Impacts of Workshop Dosage on Participant Outcomes

Twelve interviewees were repeat workshop participants (the remaining eight had only attended one workshop). Repeated participation in CE workshops was credited for teaching faculty new ways to teach and assess. It was also credited for continuing their involvement in the geoscience community. Both one-time workshop participants and repeat participants cited their involvement in the CE program and community as a key reason for their ongoing acquisition of new teaching ideas and for many it provided them continued motivation for finding and testing ways to improve their teaching and effectiveness in assessing learning. On a related note, both one-timers and repeaters appeared to have an attitude that continued appraisal and improvement of one's teaching was a central responsibility as a professor. There were repeated examples of instructors cyclically engaging in creation and revision of their courses and learning (through additional workshops, the website, and sharing with their colleagues) about how to improve their approach to instruction and assessment.

There were a few small trends with regard to repeated participation and its relation to the amount or quality of student-centered teaching approaches (see Table 5). For example, repeat attendees were slightly more likely to talk about clearly stated learning goals (feature 1) during their interviews. Interestingly, one-time attendees were a bit more likely to talk about activities that build on what students already know (feature 4), activities that are appropriate for a variety of students (feature 5), and activities that engage students in research (feature 12).

Table 5*. Evidence of Student-Centered Teaching Practices By Workshop Dosage

Teaching Features	One-time attendees (N=8)	Repeat attendees (N=12)
1. Clearly stated learning goals	Limited	Intermediate
2. Activities and assessment aligned with intended goal of the activity	Limited	Limited
3. Activity motivates and engages students; encourages student interest and attention	Strong	Strong
4. Activity builds on what students already know and addresses their preconceptions	Intermediate	Limited
5. Activity is appropriate for a variety of students	Intermediate	Limited

6. Activity engages students in independent thinking, reflection, and problem solving	Strong	Strong
7. Activity provides opportunities for students to improve their understanding incrementally	Limited	Limited
8. Activity has appropriate balance of guidance and exploration	Limited	Limited
9. Activity encourages discussion/collaboration	Strong	Strong
10. Activity has places for students to assess their own learning	Limited	Limited
11. Activity contains tips for other teachers	Limited	Limited
12. Activity engages students in data collection & analysis, observation, and experimentation	Intermediate	Limited
13. Activity helps students visualize data relationships, geologic processes, or their relationships	Intermediate	Intermediate
14. Activity requires students to integrate and synthesize ideas from different sources/experiences	Limited	Limited
15. Activity contains accurate scientific information	Limited	Limited

** Levels: limited = 0-1/3 of cases, intermediate = 1/3-2/3 cases, strong = 2/3-all cases.*

Motivations for Attending Workshops

Alumni have identified several critical differences of CE compared to other professional development offerings. One that was frequently cited was the exceptionally high quality of the core presenters of CE workshops, such as Barbara Tewksbury. These presenters make a strong impression on participants and they explain how they really standout as exceptional in their knowledge of teaching and learning as well as their skill in teaching the workshops.

The design of the workshops was frequently cited as a big difference from other professional development opportunities. The workshops are designed to reflect the student-centered approach that is advocated for in CE. This means that participants are engaged in the types of teaching activities that they are being encouraged to bring into their own teaching practices. The workshop instructors model the instructional techniques, have participants practice those techniques, and then everyone provides feedback for reflection: *"They are very hands on. You don't just sit and listen to a lecture…They have participants actually doing a lot of presentations, have small group breakout sessions and there is a lot of opportunity to interact with people."*

Many participants had a great enthusiasm for teaching prior to CE and so their motivation for attending workshops was about seeking new knowledge and skills. Yet, these instructors often reported shifts from teacher-focused approaches to students-centered approaches for teaching and learning. Thus, it seems that many experienced and/or passionate instructors still experience changes in their attitudes about teaching as result of their CE experience.

Early Career Faculty

Of course, junior faculty members were motivated for a different set of reasons to take the Early Career workshop. Some described feeling overwhelmed and not clear about their priorities. For example,

"…I was a new faculty member and I had no idea what I was getting into, of course. So I wanted to see kind of the big picture and I wanted to make sure that I was doing the right sorts of things in terms of developing research and educational program that would move me toward tenure."

Summary

This study provides some initial evidence that different types of faculty members come away from CE with slightly varied views on what constitutes effective teaching practices. While all faculty types are equally likely to come away from CE programs with a sense that strong teaching activities should engage students in problem-solving (feature 6) and encourage collaboration and discussion (feature 9), teaching faculty are much more likely to list additional features (features 4,5,10, & 14) than other groups.

Another highlight of the present interview study was that support was found for CE impacts on targeted proximal outcomes as well as more distal outcomes (e.g. faculty level vs. student level impacts). Proximal outcomes included the changes in attitudes towards geoscience teaching and course design, increased pedagogical knowledge, increased science content knowledge, increased knowledge about career management strategies, and increased awareness and ability to use educational research. A theme across these impacts was that instructors had increased their confidence in these areas as a result of these gains. In addition, they often described how they had gained the confidence and tools to be able to seek out and test new pedagogical knowledge or ideas. For more distal impacts of CE participation, frequent examples emerged for improved capacity as a professor and active designing of courses. To a lesser extent, faculty described their contributions to the geosciences community through creating and sharing of teaching methods and involvement in leadership activities to benefit geoscience education.

The interviews provided a variety of examples of how instructors shifted to a student-centered teaching philosophy and how they impact changes in their teaching methods and the ways they designed courses. We also discussed some indirect evidence of subsequent impacts on student learning that were largely interpreted from the teaching practices and classroom environments as described through the interviews. Some faculty explained how students were engaged in learning new knowledge or skills that were previously not offered through their courses or the institution at large. Our understanding of student level impacts is limited. Assessment of student level impacts was not a chief aim for this study and will have to be investigated in future research.

Limitations of the Study and Next Steps

For this limited set of interview data, the pathways of geoscience researcher, educational researcher, and teaching faculty were not readily distinctive, and it was not always clear which of these types each participant fell under. An attempt was made to categorize each participant after analyzing transcripts and the breakdown was provided in Table 2. In addition, the fourth type, early career faculty, was determined by what workshop an interviewee began their CE experience with, even if that workshop had been completed several years ago. This decision was made in order to more clearly delineate early career participants from other participants. The integration of individual responses from the geosciences faculty survey with the interview data both from this study and from prior studies of CE could provide for clearer identification of these pathways and provide a means for enhancing understanding of the different pathways in the future.

An additional limitation of the present analysis was that the pathways of CE faculty who teach at two-year institutions were not examined in-depth. There was only one representative for a two-year institution that agreed to participate, so further interviews may be desirable. Although, since a very low percentage of CE participants are from two-year institutions, this may be a lower priority for the program.

Next steps for this evaluation are to do a retrospective analysis of previously-collected interviews and look for evidence of repeated themes and areas of continuity and discontinuity between the data sources.

Appendix

Key Interview Questions and Prompts

1. Imagine that I am observing one of your classes today and paint me a picture of what I would see and how it exemplifies your approach to teaching.

- *What % of time is spent on lecture? How much of lecture involves 1:1 student interactions? what % of class/course involves active learning?*

2. What are the most important things you do as a geoscience educator?

- *How do you have an impact on students' learning?*
- *How do you have an impact on their interest or engagement with the geosciences?*

- *What are some of the issues facing geoscience education, and how has that influenced your work as an educator?*

3. In reflecting on what your teaching was like before CE and what it is like now, what would you say has been the most valuable aspect or influence of CE? How did the change or shift occur?

- *Describe what your teaching was like before CE.*
- *How have you changed your teaching methods as a result of the CE program?*
- *How have you made any (other) changes to your course design as a result of the CE program?*
- *Which course that you teach has been most influenced by CE?*

- *How have your attitudes towards teaching and learning changed, if at all, as a result of the CE program? Why do you think the changes occurred?*

- *Has your interest in participating in education research and/or your ability to use and interpret research changed as a result of your participation in the CE program? If so, how?*

- *How have your workshop experiences built on one another?*
- *How has the CE website enhanced your ability to use the things you learned at the workshop(s)?*

- *How has your participation in CE influenced your view of geoscience education or your role in the geoscience community?*
- *How has CE contributed to your ability to network with colleagues, if at all?*
- *How has CE influenced your department?*
- *Did more than one of your department faculty members go to CE?*

4. Please describe your role in the geoscience community.

- *What leadership roles have you assumed at a local, regional, or national level?*
- *How has CE influenced this?*

5. How would things be different, if at all, without your participation in CE?

- *What have been the other big influences on your teaching and professional development?*
- *How do they interact w/ CE?*

6. Do you plan to attend other CE workshops in the future?

- *If so, which ones and why?*
- *Why did you go to a CE workshop initially?*

Table 6. Workshop Attendance by Faculty Type

Faculty	Type	Exp (New=1-7yrs, Mid-level=8-15, Senior=16+)	Gender	Ethnicity	First workshop type	Repeater	Number of workshops (includes webinars)	Co-presenter	Institution type (at time of 1st workshop)
2	Educational research faculty	Was new; now midlevel	M	Wh, non-Hisp	Early career	0	1	0	private
7	Educational research faculty	Was new; now senior	F	Wh, non-Hisp	Emerging theme	1	3	1	research
9	Educational research faculty	Was new; now midlevel	F	Wh, non-Hisp	Early career	1	3	0	research
12	Educational research faculty	Senior	F	Wh, non-Hisp	Emerging theme	1	5	0	comprehensive
18	Educational research faculty	Was new; now midlevel	F	Wh, non-Hisp	Career prep	1	3	0	other
20	Educational research faculty	Senior	M	Wh, non-Hisp	Emerging theme	1	3	0	comprehensive
3	Science researcher	Was new; now midlevel	F	Asian	Design	0	1	0	research
4	Science researcher	Was new; now midlevel	F	Wh, non-Hisp	Early career	1	3	1	research
6	Science researcher	Was new; now midlevel	M	Wh, non-Hisp	Early career	1	2	0	research
10	Science researcher	New	M	Asian	Early career	1	4	1	research

11	Science researcher	Was new; now midlevel	F	Asian	Early career	1	2	0	comprehensive
13	Science researcher	New	M	Wh, non-Hisp	Early career	0	1	0	research
14	Science researcher	Senior	F	Wh, non-Hisp	Design	0	1	0	research
15	Science researcher	Senior	M	Asian	Emerging theme	1	4	1	research
17	Science researcher	Was new; now midlevel	F	Asian	Career prep	0	1	0	research
1	Teaching faculty	Senior	M	Wh, non-Hisp	Emerging theme	1	3	1	2-year
5	Teaching faculty	New	M	Wh, non-Hisp	Core geosci topic	0	1	0	public
8	Teaching faculty	Was midlevel, now senior	M	Wh, non-Hisp	Design	1	2	0	public
16	Teaching faculty	Was new; now midlevel	M	Hispanic	Core geosci topic	0	1	0	private
19	Teaching faculty	Was midlevel, now senior	M	Wh, non-Hisp	Core geosci topic	0	1	0	private

Table 7. Individual Breakdown of Evidence of Student-Centered Teaching Features (1 = present)

Faculty	Type	First workshop type	f1. Clearly stated learning goals	f2. Activities and assessment aligned with intended goal of the activity	f3. Activity motivates and engages students; encourages student interest and attention	f4. Activity builds on what students already know and addresses their preconceptions	f5. Activity is appropriate for a variety of students	f6. Activity engages students in independent thinking, reflection, and problem solving	f7. Activity provides opportunities for students to improve their understanding incrementally
2	educational research faculty	ec			1			1	
7	educational research faculty	emerging theme	1	1	1		1	1	
9	educational research faculty	ec						1	
12	educational research faculty	emerging theme			1	1		1	
18	educational research faculty	cprep	1	1	1			1	
20	educational research faculty	emerging theme						1	
3	science researcher	design							
4	science researcher	ec	1		1			1	
6	science	ec			1			1	

	researcher								
10	science researcher	ec	1	1	1			1	1
11	science researcher	ec			1	1	1	1	
13	science researcher	ec	1	1	1		1	1	
14	science researcher	design			1	1	1	1	1
15	science researcher	emerging theme			1	1		1	
17	science researcher	cprep						1	
1	teaching faculty	emerging theme	1	1	1			1	
5	teaching faculty	core geosci topic			1	1		1	
8	teaching faculty	design			1			1	
16	teaching faculty	core geosci topic			1	1	1	1	
19	teaching faculty	core geosci topic			1		1	1	

Faculty	Type	First workshop type	f8. Activity has appropriate balance of guidance and exploration	f9. Activity encourages discussion/collaboration	f10. Activity has places for students to assess their own learning	f11. Activity contains tips for other teachers	f12. Activity engages students in data collection & analysis, observation, and experimentation	f13. Activity helps students visualize data relationships, geologic processes, or their relationships	f14. Activity requires students to integrate and synthesize ideas from different sources/experiences	f15. Activity contains accurate scientific information
2	educational research faculty	ec		1						
7	educational research faculty	emerging theme		1			1	1		
9	educational research faculty	ec		1			1	1		
12	educational research faculty	emerging theme		1			1	1		1
18	educational research faculty	cprep		1			1		1	
20	educational research faculty	emerging theme		1						
3	science researcher	design		1						
4	science researcher	ec		1			1	1		
6	science researcher	ec		1				1		

10	science researcher	ec		1	1					
11	science researcher	ec		1					1	
13	science researcher	ec	1	1						
14	science researcher	design		1						
15	science researcher	emergin g theme		1				1		
17	science researcher	cprep	1	1	1		1	1	1	
1	teaching faculty	emergin g theme		1					1	
5	teaching faculty	core geosci topic		1	1		1			
8	teaching faculty	design	1				1	1		
16	teaching faculty	core geosci topic		1	1			1		
19	teaching faculty	core geosci topic		1			1		1	

Appendix C: Adapted Lesson Plan Analysis Tool

Lesson Plan Analysis Tool (Adapted from the Science Lesson Plan Analysis Instrument (SLPAI)*)
1=Needs Improvement, 2=Making Progress, 3=Exemplary; NA=Not able to determine

Content accuracy (15)	1	2	3	NA
Content presentation – level of detail and abstraction, sequencing, examples	1	2	3	NA
Nature of science – tentative nature of knowledge based on changing evidence, social process involving argumentation	1	2	3	NA
Student engagement – requires active participation of students in their own learning	1	2	3	NA
Pre-assessment – teacher solicits student ideas in order to plan instruction	1	2	3	NA
Classroom discourse – lesson is structured to require and promote sense-making discussion among students	1	2	3	NA
Variety – Teacher innovation or creativity keeps teacher and students engaged	1	2	3	NA
Student practitioners of scientific inquiry –inquiry skills are taught in context	1	2	3	NA
Analytical skills – students are supported in drawing or refuting conclusions based on evidence	1	2	3	NA
Student reflection – students reflect on and summarize their understanding (6)	1	2	3	NA
Goal orientation – includes changing student values, attitudes, or beliefs	1	2	3	NA
Assessment – emphasizes conceptual understanding, includes grading rubric	1	2	3	NA
Student problem solving – students engage in PBL (6)	1	2	3	NA
Clearly stated learning goals (1)	1	2	3	NA
Learning activity and assessment alignment with the learning goals (2)	1	2	3	NA
Student engagement in data collection & analysis, observation, and experimentation (12)	1	2	3	NA
Prior knowledge – builds on what students already know and addresses preconceptions (4)	1	2	3	NA
Activity motivates and engages students; encourages student interest and attention (3)	1	2	3	NA
Activity is appropriate for a variety of students (5)	1	2	3	NA
Activity provides opportunities for students to improve their understanding incrementally (7)	1	2	3	NA
Activity has appropriate balance of guidance and hands-on exploration (8)	1	2	3	NA
Activity requires collaboration/discussion (9)	1	2	3	NA
Students assess own learning (10)	1	2	3	NA
Activity helps students visualize data relationships, geologic processes, or their relationships (13)	1	2	3	NA
Activity requires students to integrate and synthesize ideas from different sources/experiences (14)	1	2	3	NA
Appropriate use of technology	1	2	3	NA

* Jacobs, C. L., Martin, S. N., & Otieno, T. C. (2008). A Science Lesson Plan Analysis Instrument for Formative and Summative Program Evaluation of a Teacher Education Program. Science Education, 92(6), 1096-1126.

NOTE: Alignment of items with the On the Cutting Edge Features of a Strong Teaching Activity is indicated with a number in parentheses.