

InTeGrate Faculty Study

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Executive Summary

This evaluation of InTeGrate focuses on assessing faculty engagement in improving STEM education in substantive and important ways, including changing pedagogy and materials, instructional strategies, assessment, and collaborations with other faculty through teaching communities and other professional development opportunities. The data for this study were collected via semi-structured phone interviews. A total of 51 faculty participated in the study and represented one of three groups: material developers (21), mentored faculty (15), and unmentored faculty (15). The interviews averaged approximately 30 minutes, were audio-recorded, transcribed and iteratively coded to identify major themes and patterns per faculty group and across groups.

Overall, the results reveal positive feedback from faculty on InTeGrate being a beneficial program with well-constructed materials and resources leading to faculty, and in some instances, institutional changes. Opportunities for collaboration, for improving teaching, and for building teaching communities were found to be highly valuable by the faculty interviewed for this study, with many faculty expressing hope that activities associated with InTeGrate will continue.

Many material developers incorporated more active learning pedagogies into their teaching. The guiding principles influenced their teaching and assessment, however, which guiding principles were most impactful differed by disciplines. The impact on teaching communities ranged from none to very large changes and new collaborations, which occurred across disciplines. The impact on departments or institutions again ranged from none to helping to facilitate large institutional interdisciplinary changes. The facilitation of institutional or department change occurred where there was momentum for interdisciplinary, sustainability curriculum changes, and InTeGrate was used as a model and resource to support those changes.

Mentored faculty often increased active learning techniques in class after participation and nearly half also changed assessment techniques. The guiding principles that most often increased after being part of an implementation group were *interdisciplinary problem solving*, *systems thinking* and use of *grand challenges*. The impact of participation on faculty teaching communities ranged from none to many new colleagues and collaborators and joining the larger InTeGrate teaching community. A wide range of departmental impacts also occurred and many faculty spoke of potential future impacts.

The unmentored faculty teaching changes ranged from none to an increase in active learning techniques, use of guiding principles and changing assessment techniques. The change to teaching communities similarly ranged from none to multiple collaborations and facilitating academic productivity. The departmental and institutional impacts were also varied from none to using InTeGrate materials as a tool to help increase active learning throughout an institution.

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Introduction

InTeGrate is a STEP (STEM Talent Expansion Program) Center grant funded by the National Science Foundation (NSF) beginning in 2011 and extending through 2016, with an extension through 2018. A primary goal of InTeGrate is to engage faculty in improving STEM education in substantive and important ways, which is reflected in the following statement:

[The goal of InTeGrate is to enable] a group of faculty representing a cross section of institutions of higher education to identify a national challenge or opportunity in undergraduate education in science, technology, engineering, and mathematics (STEM) and to propose a comprehensive and coordinated set of activities that will be carried out to address that challenge or opportunity within a national context.

InTeGrate focuses on two critical goals that help to operationalize its scope of work and intended outcomes. The first is to develop curriculum, including developing and testing new materials, to support the implementation of new courses. This goal also involves assessment of the implementation of new materials and courses on students' geoscience literacy and the ability to make sustainable decisions, including assessing the potential impact of these new programs on historically under-represented students and future K-12 education teachers.

A second goal of InTeGrate is to prepare students for the workforce and a sustainable future by developing, documenting and disseminating new model programs that include a strong interdisciplinary component. The programs strive to achieve this goal by engaging students in issues of sustainability and providing them with a pathway from K-12 education to a STEM degree, broadening access and participation among under-represented groups, spreading geoscience programs to minority-serving institutions, and preparing teachers to deliver introductory geoscience content. Another important aspect of this goal is to assess the impact of InTeGrate on the number of students in geoscience majors, and "students' ability and motivation to use insights from the geosciences in addressing grand challenges of sustainability."

In terms of InTeGrate's deeper work with faculty to help bring about these curricular and instructional changes, the following five guiding principles were established for the development and implementation of teaching materials:

- Connect geoscience to grand challenges facing society (*grand challenges*)
- Develop students' ability to address interdisciplinary problems (*interdisciplinary problems*)
- Improve student understanding of the nature and methods of geoscience and developing geoscientific habits of mind (*geoscientific thinking*)
- Make use of authentic and credible geoscience data (*authentic data*)
- Foster systems thinking (*systems thinking*)

Faculty who engage in this materials development, pedagogical change, and other aspects of reform are encouraged to access and use these guiding principles in creating learning objectives and goals, in their assessment and measurement work, and in developing resources, materials, and instructional strategies. These aspects of the Center's portfolio provide a useful framework for evaluating how faculty engage with InTeGrate and how they perceive the impact of their participation in the project.

Evaluation Process

The Community College Research Initiatives (CCRI) group was contracted by SERC to conduct a qualitative study on the engagement and perceived use and impact of the InTeGrate project on material developers, implemented programs and the Quantitative Undergraduate Biology Education and Synthesis (QUBES) participants, and webinar and professional development participants.

At this important concluding point for InTeGrate, it is important to follow-up with these three key groups to understand how they have been involved and how their involvement has influenced their professional practice and the professional practice of others affiliated with them.

The purpose of this evaluation is to examine faculty engagement in InTeGrate and their perceptions of program impact. The evaluation was guided by the following questions:

1. What is the impact of the InTeGrate project on changes in pedagogy, teaching, courses, programs, institutions and the use of InTeGrate's five guiding principles?
2. What is the role of the InTeGrate project in fostering teaching community participation and interactions?
3. What are the emergent impacts associated with participation in the InTeGrate project?

SERC provided names of individuals in the three groups who were predominately working in faculty positions in 2-year and 4-year colleges and universities, from which our CCRI team sampled: 1) faculty creators of ideas and materials, the material developers; 2) faculty who were mentored on InTeGrate guiding principles and materials via implementation programs or the QUBES program; and 3) unmentored faculty adopters who participated in various InTeGrate events such as webinars, workshops, and Earth Educators' Rendezvous. A purposive subsampling process was created for each group with SERC's input. The subsampling focused on faculty who have not been previously evaluated, and who represented multiple modules, a variety of implementation programs and QUBES and different webinar and workshop experiences.

The goal was to interview 50 faculty from the three groups described above, with similar sample sizes for each group. In total, 52 faculty were interviewed, and one was removed from the sample because the participant did not meet the sampling criteria, which yielded a total of 51 faculty for inclusion in the data collection and analysis.

Table 1. Sample Per Group

Groups	Number in Group	Description	
Material Developers (MD)	21	2-year faculty: (3) geoscience 4-year faculty: (7) geoscience, (8) non-geo natural sciences and engineers, (3) non-geo social science and humanities	17 modules represented
Mentored faculty (IP & QUBE)	15	2-year faculty: (2) geoscience, (2) non-geo natural sciences 4-year faculty: (7) geoscience, (4) non-geo natural science	6 implementation programs or the QUBES program represented
Unmentored faculty (Webinar & PD)	15	2-year faculty: (3) geoscience, (2) non-geo natural sciences 4-year faculty: (8) geoscience, (2) non-geo natural sciences	Not applicable

Sub-sampling attempted to obtain equal gender representation. Also, recognizing that institutional context may impact outcomes, an additional goal was to represent the full range of academic disciplines and institution types. Table 2 summarizes the representation of the overall sample on demographic, disciplinary, and institutional characteristics.

Table 2. Sub-sampling categories

Category				
Sex	Female	53%	Male	47%
Discipline	Geoscience	59%	Non-geoscience	41%
Institution Focus	Minority Serving Institutions (MSI)	14%	Predominantly White Institutions (PWI)	86%
Institution Type	2-year	22%	4-year	75%
Institution Control	Public	76%	Private	22%

Scripted invitation emails were created with input from Dr. Ellen Iverson, SERC Evaluation Director, to solicit participation from material developers and implementers, as SERC has a relationship with many of the faculty. Dr. Iverson sent out the initial email and the evaluators followed up within the week and scheduled interview times with respondents. The evaluation team contacted webinar and workshop participants directly to invite them to participate in the study. The interviews were conducted by phone.

To calibrate the interviews and standardize the interview process both evaluators attended each other's first five interviews. The interviews began with a script describing the purpose of the study, providing an overview of the interview questions, and obtaining permission for audio recording.

The interview protocols (see Appendix A & B) were co-created with SERC's input and were tailored for each of the three groups. All of the interviews were conducted individually (except for the initial interviews to calibrate) and each interviewer followed the script fairly closely. The interviews ranged from 13 to 74 minutes long, with an average of approximately 30 minutes.

Recorded interviews were transcribed, and all transcripts were iteratively coded to answer the research questions and to look for emerging themes. The first round of coding involved descriptive coding and codes were added and adapted throughout the process. Once this phase was complete, the data were secondarily coded for analysis.

In the following section of the report, we analyze and present results for each group separately, organized by research questions. Quotes are used throughout to highlight findings, provide faculty voice, and also describe exemplars of collective and unique phenomena. In addition, we analyze the data across groups to identify findings that apply to more than one group. These themes are discussed in the conclusion of the report.

Results

Material Developers (N=21)

Overall Changes

Results show that faculty who participated as material developers made numerous changes to their teaching. Almost all faculty who did not previously teach with active learning principles in their classes adopted new teaching techniques and pedagogies, and those who already used active learning techniques made modifications to their teaching, such as changing student assessment, incorporating more group work, and using more real-world examples.

Faculty valued the interdisciplinary collaborations and perspectives they gained from engaging with others outside their disciplines and institutions. Many faculty from all disciplines discussed *interdisciplinary problems* within courses more often and others engaged in more interdisciplinary collaborations after being material developers. Material developers also used several other guiding principles more frequently in classes after their experience, such as *systems thinking*, *grand challenges* and use of *authentic data*. Implementation of these guiding principles varied by geoscience and non-geoscience faculty.

The impact to teaching changes, community creation, and larger department or institutional changes varied between disciplinary groups. Therefore, the subsequent analysis is divided into 1) humanities and social scientists, 2) natural scientists and engineers, and 3) geoscientists. The humanities and social science faculty were the smallest group (N=3), followed by natural scientists and engineers (N=8), and geoscientists (N=10).

Humanities and Social Scientists Materials Developers (N=3)

Pedagogy and materials. The humanities and social science faculty were already using active learning techniques in their courses, but incorporated other new teaching strategies as a result of their experience as material developers. All reported using more real-world case studies in the course the module was created for, and one said she began using case studies in another class as well. One faculty member engaged his students through more group work in class. Another faculty member was influenced by a workshop and adjusted assessment strategies in a number of her classes to focus more on metacognition and having students reflect on what they are learning. For all three faculty, the module material was only used within the classes they were created for, as it was not applicable in other classes they taught.

Guiding principles. All faculty appreciated the opportunity to work on curriculum in an interdisciplinary team. Two faculty saw impacts of the guiding principle, addressing *interdisciplinary problems*. The political scientist who mainly teaches science and engineering students felt the interdisciplinary work in the module allowed her students to better understand how their majors interact with policy and politics. Another faculty member explained that the experience of working with people outside her discipline allowed for a more *interdisciplinary* understanding and problem-solving focus within the module course and other courses. Reflecting on the evolution of her teaching practice, the faculty member said,

That was really the big difference between teaching then versus teaching now. A student would see me in the classroom now really trying to incorporate other ways of thinking and pushing them to try to problem solve.

Beyond interdisciplinary understanding of problems, one faculty member also added the guiding principle of *systems thinking* to several courses, and strengthened two other guiding principles in her course, *geoscience thinking* and *using authentic data*, with the use of the module. Another faculty member explained how *systems thinking* and *using data* expanded his teaching.

It's kind of taking aspects to be able to expand understanding and develop an ability to make use of credible data. It's definitely incorporating more of a systems approach to thinking, is what it really expanded upon in my teaching.

Community of practice and continuing professional development (PD). Faculty covered the full spectrum on their engagement in communities of practice as it relates to involvement in InTeGrate. One faculty member said there had been no change in their teaching and learning community, whereas another said InTeGrate had been a “conversation starter” with colleagues in different departments about active learning and pedagogy. The third faculty member considered InTeGrate “life changing.”

It's been, it's life changing... with the collaborations. Like I said before, I had not really worked with people in different fields before. It's like now I can't think of myself as not working with people in other fields.

This faculty member now seeks out other people outside her discipline to see “who might have different pieces of the puzzle to be able to add to solving a problem.” Her desire for interdisciplinary problem solving has led to a collaboration with someone in the chemistry department at her college on how to educate the local community about air quality issues.

All interviewed faculty said they plan to continue to be part of PD focused on earth science or the intersection of science and social issues, in order to learn from interdisciplinary perspectives and from colleagues focused on active learning.

Departmental and institutional change. Departmental changes identified by the faculty were modest, with only one faculty member noting that there had been an increase in interdisciplinary perspectives within the curriculum in their department. No institutional changes were attributed to InTeGrate work.

Natural Scientists & Engineers (N=8)

Pedagogy and materials. Several of the natural science and engineering faculty described their increased use of different teaching strategies, pedagogies, and active learning techniques in their classrooms, which corresponded with a decreased use of lecturing. However, two faculty said they did not change their pedagogy as they were already using active learning techniques. Another faculty member attributed her increased use of real-world problems and geoscientific examples in her course to InTeGrate. One faculty member also felt students were more engaged after he ‘flipped’ his classroom and students were able to determine the direction of class. For another faculty member

interviewed, teaching changes included using more formative assessment and metacognition in her courses.

Most InTeGrate modules were used in the classes for which they were created, and some were also used in classes where the faculty felt they had a good ‘fit’. However, for these faculty, the new pedagogical practices were implemented in multiple courses beyond the initial module courses.

Guiding principles. Four faculty incorporated more of the guiding principle of *systems thinking* into their classes, and three also integrated *interdisciplinary problems*, *authentic use of data* and real-world problems. A faculty member said she had already been incorporating all principles prior to becoming a materials developer, but was able to add more *geoscientific thinking* afterward. Another faculty member said she incorporated all five guiding principles into the assessment for several activities within a course, noting:

[I]nstead of just having an assessment based on what I hope students are getting out of it, now I have a whole range of activities that include all five of those guiding principles that are woven throughout my course.

Community of practice and continuing professional development (PD). For some faculty (N=3), their teaching community of practice did not grow beyond their co-authors, but for others, it led to further engagement with the InTeGrate community as a mentor, webinar presenter, and conference presenter of InTeGrate materials. Some faculty also found that the community that was created during workshops was helpful for discussing and creating interdisciplinary curriculum. For one faculty member, her InTeGrate work led to a conversation with a colleague in a different department about the module, which later led to a co-taught course. For another, an interdisciplinary community that was created was impactful because it gave her many other people and perspectives to use as resources for improving her teaching practice. The following quote from a natural scientist exemplifies what many articulated about the impact of InTeGrate on their teaching community of practice.

I think maybe the biggest take away is that we can learn a lot from each other, really. And the InTeGrate project has really brought me together with a lot of people that I never would have met before who have a lot of great ideas, who work in really different settings, who have opened my mind up to a whole community of people working on a huge range of things. So, I would say this was the aspect of a community [that has] been most valuable for me.

All but one faculty member said they would continue seeking PD focused on earth science or the intersection of science and society for various reasons, noting the desire to focus on interdisciplinary problems and solutions, improve teaching, give back to the geoscience teaching community, and be part of a larger community working on pedagogy.

Departmental and institutional change. Four faculty said there was no change to their program or institution, but one faculty member noted that InTeGrate helped improve the curriculum for a science major. Another said it led to discussion with colleagues about the modules and active learning. Another faculty member reported that she and two faculty from two different departments at her college went to an Earth Educators’ Rendezvous, which has led to conversations that may potentially result in larger institutional level changes around interdisciplinary curriculum.

Geoscientists (N=10)

Pedagogy and materials. All geoscience faculty who were not already incorporating active learning into their classes prior to InTeGrate (8 of 10), said they increased active learning in their classrooms and decreased the amount of lecturing as a result of their participation in InTeGrate. A few began utilizing the flipped classroom model, which involves more participatory learning in class and learning content outside of class time.

Two faculty who were already using active learning methods appreciated what they gained from being a part of the curriculum development process and valued working with an interdisciplinary and interinstitutional team. Another faculty member noted the shift in his teaching from covering content to focusing on key learning goals and a more “simplified and deliberate” assessment of those goals.

I think maybe one of the things I learned during the time of InTeGrate was, boy, the majors aren't learning. They're not learning everything I'm lecturing about – they learn when it's connected somehow to their lives, their town, their whatever... So I backed off on content on this big overarching or broad corpus of knowledge and really focused on some key things. You know, from 12 learning goals [I] went down to two or three.

Another faculty member said the experience with InTeGrate increased his content knowledge and thus made his “instruction better.” All faculty were using the module material they developed in the class for which it was designed, and some also used modules in other classes.

Guiding principles. Most geoscience faculty mentioned *authentic data*, *grand challenges*, *systems thinking* as important in their courses, and some faculty also mentioned *interdisciplinary problems*. The faculty member quoted below explains the importance of the guiding principles to her teaching.

I would have to say, that is one of the most important things I got out of developing that module is that those five principles, I basically have tried to incorporate those into every course.

Many faculty said they were already focused on *geoscientific thinking* before becoming involved in InTeGrate, but one faculty member described being more deliberate about focusing on it. Other results revealed that one faculty member was using *grand challenges* in all classes, *authentic data* in most classes and *interdisciplinary problems* in some. A second member focused on *interdisciplinary* understanding of the *grand challenges*, and a third said *systems thinking* and *interdisciplinary* connections were made more 'explicit' in class.

A fourth faculty member described how the authentic use of stream data in class led to a student gathering more data for a senior project and sharing the results with a local agency. This ultimately led to a stream restoration plan, which directly impacted the local environment.

Several faculty interviewed wanted to help students understand *grand challenges* and felt it was their role to help contribute to the solutions and understanding of those grand challenges. Below is a quote from a faculty member describing how he saw his role as an educator was tied to *grand challenges*.

Ultimately, I can't do my job as an educator in isolation where there are real world problems, period... I need to use my scientific perspective and the fundamental facts that my science contributes to our society, and I have to make sure that people begin to implement changes that are going to protect human resources and economic resources to the betterment of future generations. If I'm not part of that solution, then I should not be in this role, quite honestly.

Community of practice and continuing professional development (PD). Several geoscience faculty said they appreciated having a community of people at events and as material developers “interested in improving geoscience education and teaching”. Several faculty presented or had written papers with co-authors and kept in touch after the material development was over. Two faculty discussed the benefit of having time to focus on curriculum as well as the usefulness of the support provided in the process. This faculty member reflected on the value of his experience.

So, working with the people on my team to develop the module and working with the folks who were kind of in the organizational and review part... that was really the most valuable thing was having that time to actually do that and also having the support structure to make sure that what we were doing was high quality and made a lot of sense

Another faculty member noted that working with co-authors from different institutions and disciplines generated conversations about pedagogy and curriculum that would not have happened otherwise. For one faculty member, InTeGrate helped frame a discussion about interdisciplinary curriculum for his institution. A faculty member felt like a role model for active learning in her department and began facilitating more conversations about learning with fellow faculty. Another faculty member was able to discuss curriculum design with colleagues outside her department after module development.

All faculty said they would continue participating in PD focused on earth education, but one faculty member was looking for more interdisciplinary and less geoscience-focused PD in the future. Their reasons for continuation included a desire to improve teaching and wanting to be part of a supportive geoscience teaching and learning community. For one faculty member in particular, that community was important as he did not have one at his institution, saying “[I need] something to keep me interacting with people, getting new ideas, staying excited about the subjects.”

Departmental or institutional change. Several faculty said more conversation about teaching and learning was occurring in their department, and one faculty member cited more interdisciplinary discussions in the classroom after module development. He described how he brought in environmental justice material learned at an Earth Educators’ Rendezvous, and another faculty member said most of the department had participated in InTeGrate so a large emphasis on grand challenges had emerged throughout the curriculum.

Two faculty described how their InTeGrate experience helped facilitate interdisciplinary curriculum at their institutions. One of the faculty member shared that InTeGrate “helped with a ground swell” of interdisciplinary discussions on curriculum and teaching and helped facilitate an interdisciplinary sustainability program. He also noted that it “allowed us to break down those barriers. We saw a lot more opportunities for collaboration” between disciplines. Below is a quote from the other faculty member describing how InTeGrate was a resource for their creation of interdisciplinary, sustainability curriculum.

InTeGrate has given us some great experience in how to design a program to really consider the pedagogic effectiveness, the outcomes-based approach to thinking about our curriculum development that we want to do with our colleagues in business and humanities around sustainability education, so InTeGrate has been a great resource.

Two material developers did not see departmental or institutional change, and one attributed this lack of growth to an absence of leadership support at their institution. The other attributed it to being the lone geoscientist in his program.

Mentored Faculty (N=15)

Overall Impact

Faculty who participated as mentored faculty in the implementation programs and QUBES improved their teaching by incorporating InTeGrate's curriculum content, as well as new teaching and assessment techniques. Exposure to new ideas offered in the modules and other resources (such as webinars and workshops) opened up additional conversations about pedagogy and STEM equity for some, and also increased interdisciplinary conversations about teaching for others. Overall, the guiding principles of the InTeGrate modules that impacted faculty the most were addressing *interdisciplinary problems, systems thinking* and *grand challenges*.

The mentored faculty talked about the significant amount of time it takes to re-design a course and how InTeGrate's plug and play modules create opportunities and ease of change for those who would not otherwise try new teaching content or methods. Among all of the various starting points on the spectrum towards cultivating active learning environments, the mentored faculty discussed how they have shifted even further in this direction via pedagogical changes. Faculty also described the innumerable benefits gained from being part of a teaching and learning community of practice, which for some, led to changes in their departments and institutions around student outcomes and teaching practices.

Pedagogy and Materials

Most (10 of 15) of the mentored faculty said they became less reliant on lectures and used more active learning techniques in their classrooms after participating in InTeGrate. For some, this shift meant more discussion, and letting students' questions drive the direction of the lecture. Conversely, they reported spending less time on giving information to students and instead providing space for more research and discovery in the classroom. Below is a quote from a non-geoscience faculty describing the changes active learning pedagogy created.

The ultimate thing is [that] students do a lot more out-of-classroom work to come to class, and then actively engage in conversation or in dialogue or in sharing solutions to problems, and InTeGrate helps them do that.

These changes also led to more group work in class, critical thinking activities, and engaged students. Often, these kinds of pedagogical modifications were incorporated in multiple classes. One faculty member observed that a large-scale project kept the students more engaged and focused, and another began using more diverse examples in class and relating the material to socio-economic issues so that

students could connect with it. The experience for one geoscience faculty member also generated an increased excitement for work.

I think you'd probably also see I'm a little bit more enthusiastic about my teaching. I've probably always been passionate about it, but I'm definitely more passionate now than I was before I started working with InTeGrate. I think my compassion level, my understanding of the material, being able to collaborate with other people really shows a lot in the classroom.

One faculty member did not report making any teaching changes because he saw himself as a person who already incorporated teaching strategies that were similar to InTeGrate's recommendations. However, he said the implementation program prompted fellow faculty to use more active learning techniques in their classes. Two other faculty changed content more than style, such as adding sustainability or climate change themes and examples throughout their courses. One faculty member did not make teaching adjustments because he has not been able to teach the course since it was created.

Nearly half of the faculty said their use of classroom assessment changed, and one said it is something he plans to work on in the future. All moved beyond just summative assessment to add the following types of assessments:

- Encouraging students to become subject matter experts and report out in class
- Relating assessment to students' daily life
- Utilizing multiple types of assessment
- Incorporating assessment focused on critical thinking

One geoscience faculty member describes moving away from traditional summative assessment and toward using clickers and other types of in-class assessment to evaluate student knowledge, which she said freed up time to do more inquiry in class.

Assessment was - before, there were a lot more exams and actually doing lab exercises... There's a lot more assessment for general participation and being actively engaged and interested and asking questions. There's a lot more assessment for short papers, which take the material and think about it in a new way... Also, I have assessments now for doing pre-class readings.

Unlike the pedagogical and assessment improvements which were integrated into many courses that the faculty taught, the module material adapted for these implementation programs tended to be used in the courses for which they were designed. One faculty member talked about using the examples from the modules on climate change and sustainability in other classes when they were appropriate.

Guiding Principles

For the mentored faculty, many of the guiding principles of InTeGrate modules had an impact on their classes. *Interdisciplinary problem solving*, *systems thinking* and *grand challenges* were mentioned by a majority of faculty. Also, most faculty reported increasing the *interdisciplinary* focus of their classes, with one geoscience faculty saying this focus led to a deliberate effort to increase interdisciplinary interactions in the college.

I used to think that it wasn't a very important part, the social science aspect of things, but now I think it's an absolutely huge part of what we teach. We need to integrate that within our classes. They also have a very, very excited attitude to now start to develop some of our materials into their social science classes.

Many of the mentored faculty said the use of *authentic data* and real-world examples were also important. The natural scientist (quoted below) felt *authentic data* helped his students improve both their scientific thinking and understanding.

...being able to pull in real data and use that as a way to model scientific thinking is quite helpful, and using it as a way to demonstrate the principles that we're talking about is quite helpful.

Community of Practice and Continuing Professional Development (PD)

The implementation program or QUBES led to the formation of teaching communities, and faculty credited these groups with helping them to improve instruction, start conversations around teaching within departments and across disciplines, and provide teaching support. Below is a quote from a geoscientist about the support he feels from his teaching community.

I can't imagine a time in my life now where I would want to get out of this community. It's been so beneficial to me.... it's such a great community of people. People are there to answer questions. People are there to help you through problems.... It's a huge support group. The people on the other end of that support group, whether that be me helping somebody else out or me reaching out to somebody else, has always been an amazing experience for me.

One non-geoscientist faculty member discussed how this was her first effective and productive teaching community. This faculty member said the teaching community that she was a part of modified multiple courses in multiple disciplines around sustainability, and they also participated in multiple scholarly endeavors together. She credited the teaching community with seeing a need for change and having the materials from InTeGrate to make the changes.

We all presented professional presentations together, we went to meetings together. We're all writing up manuscripts on this. And that's something that, you know, I've never had a collaboration, in terms of curriculum, that's been as productive as this....the best part is we didn't have to create the material, it was already there, we just needed to modify it for our classes.

There was an array of other outcomes from the teaching communities created with these implementation programs. A faculty member noted that the teaching community facilitated discussions in her program around gender equity. Two faculty members said it enabled them to join a teaching community that already existed on their campuses. Two other faculty described how their mentored work led to them attending Earth Educators' Rendezvous, and learning more while participating in the "community there in that moment". Another faculty member discussed how this work prompted him to conduct more outreach and provide science education to the community and local high schools.

Those who had little to no continuation of their teaching collaborations had multiple reasons for the collaborations ending. One faculty member had colleagues who were not interested in infusing climate

change into the curriculum, while another faculty member stated that he was the only person in his department who teaches what he does, which gives him minimal opportunities for discussion around teaching. Another faculty member, despite being the only one at his institution in his discipline, mentioned wanting to continue collaboration but cited a lack of time as a barrier, due to his research obligations and to a current family emergency.

All faculty interviewed said they would continue to be a part of PD focused on earth education or science and society. The reasons they gave for their continuing involvement in this type of PD fell into five groups: 1) the importance of the subject matter, 2) the ability to enhance the relevance of their classroom teaching, 3) the enhanced ‘reach into the community’, 4) the opportunity to educate society, and 5) the need for interdisciplinary understanding to communicate about and solve grand challenges. Below is a quote from a faculty explaining how she sees her roles as an educator tied to *grand challenges* and address *interdisciplinary problems*, and thus why she will continue PD.

I think moving forward with our issues that we have on the planet, we've got experts working to help solve them, but we also need communicators and educators to be able to explain to people why things are the way they are, what we can do to help solve them. You have to have educators that are not only aware of the science, but also the social issues and that's why I don't plan to change what I'm doing, because they can't just be silos unto themselves.

Departmental and Institutional Change

For several faculty, departmental or institutional change took the form of taking teaching more seriously, strengthening student learning outcomes, increasing discussions about teaching, and increasing collaboration with other institutions. One faculty member stated that the InTeGrate work led to discussions about gender equity in STEM within her program.

[I] facilitated a workshop with another person on discussing issues regarding gender equity in the classroom. That's the first time we've ever discussed that as a program, and we invited people from other STEM sciences as well. I think that opened up some communication that I think that nobody had really even had the discussion over coffee, so I think that was a big value for the implementation program in our program and now our university is kind of opening those doors for discussion.

Another faculty member said InTeGrate work resulted in improved recruitment and retention in the program and led to the development of relationships with local community colleges. Several discussed how their mentored work will impact future majors, minors, and endorsements, and only a few reported no programmatic or institutional changes.

Unmentored Faculty (N=15)

Overall

Faculty who participated as unmentored faculty in the webinars and workshops experienced a variety of impacts on their teaching, ranging from no changes to using more active learning techniques in class, and incorporating guiding principles and assessment changes. Teaching communities and

collaborations ranged also from no change to developing new partnerships with surrounding institutions. Two of the four faculty who only participated in webinars did not generate new collaborations or community as a result of that experience. However, it should be recognized that the webinars were not designed with teaching community creation as an intended outcome.

Similar to the mentored faculty group, these faculty appreciated the time-saving aspect of InTeGrate's modules, which enabled them to try new approaches and materials in class. The influence of the guiding principles was evident in an increased focus on *grand challenges* and use of *authentic data* and *interdisciplinary* understanding by several faculty, and *systems thinking* for a handful. Departmental and institutional impact also had a broad range, from no impact to influencing interdisciplinary curriculum design.

Four of the faculty interviewed only attended webinars, and the other eleven attended one or multiple Earth Educators' Rendezvous (EER), workshops, and webinars. The impacts to teaching, community creation, and departmental or institutional changes varied between groups and are discussed separately below.

Pedagogy and Materials

For two of the four faculty who participated in webinars only, there was no change to their teaching techniques or use of materials. For one of those faculty who only taught singular short class periods as a guest teacher in secondary education classrooms, the modules were not appropriate for her needs. The second webinar-only faculty member with no teaching change was already using many active learning techniques, but also found the modules too in-depth for her general education classes.

The other two webinar-only faculty used parts of modules in class, and one increased the use of active learning techniques. The other faculty member was already promoting active learning in class and felt the modules allowed for more access to "something that might be more relevant, up-to-date and data-rich," and also connected to students' daily lives.

The other eleven faculty who were part of the unmentored group participated in Earth Educators' Rendezvous (EER) and many also participated in other workshops and webinars. Almost all of these eleven faculty said their experience led to the use of more active learning techniques in the classroom, both for those new to active learning and for veterans of active learning, in which the experience allowed them to further develop their pedagogy. Below, the first quote is from a non-geoscientist faculty member who found the InTeGrate resources valuable for greater student engagement. The second quote is from a geoscientist faculty member who reported adopting more active learning activities.

I think the thing that was most amazing was just having such a rich resource of materials trying [to] incorporate more active learning, and really engage students in the classroom. (Non-geoscientist faculty)

So, I actually flipped the class more than I had before. I gave them all pre-assignments for almost every lecture, so they had to do a short, targeted reading or watch a short video or something like that and answer a couple questions before coming to class. So, I could spend less time on lecture and more time with them actually doing stuff. (Geoscientist faculty)

As a result of the resources provided by the modules, another faculty member saw changes in the depth of student work, which he felt led to better student products. This perspective is evident in the following statement.

[The students are] using a greater breadth of resources than what they were using before. Many of these are resources that have been assembled, and streamlined, and made very efficient, because of the work of others.

Another faculty member indicated that InTeGrate helped her focus on what is important for student learning outcomes.

...it's very easy for me to get lost in the content....and InTeGrate forces me to take a step back and say, "Okay, wait a minute. Aside from the topic, what's the overall goal here? What do I want the students to retain, what do I want them to learn? What do I want them to be able to apply?" Not necessarily getting lost in the content but the overall big picture, and that's very valuable to me.

A final faculty member was inspired by her InTeGrate experience to create more interdisciplinary courses and also to focus the core of her course around sustainability.

Guiding Principles

Two webinar-only faculty said they were already incorporating several of the guiding principles into their teaching. Two others said it helped them use *authentic data* and one of the two also used more *interdisciplinary problems* and *systems thinking* in his courses.

Several EER participants said they already focused on *grand challenges* in their courses, but most said they increased focus on those challenges after the workshops. Most used *authentic data* or real-world examples more in class and a majority increased their use of *interdisciplinary* understanding of problems as well. One geoscience faculty member shared that the guiding principles aligned with her course goals, and the InTeGrate resources facilitated connecting those course goals to students' lives.

[W]hat the InTeGrate materials have done I think to help me with that is being able to think of activities, classroom design that allow me to address those, and I think some of the big ones are the authentic data, the systems thinking, and the grand challenges. All of those are things that can help my students, one, improve their data skills, but also connect the concepts to their own lives.

Community of Practice and Continuing Professional Development (PD)

For two faculty, webinars did not lead to a change in their teaching community. However, two webinar-only faculty, and three workshop faculty said their experiences led to productive conversations with their colleagues about teaching. Two faculty described how their workshops enhanced an already existing collaboration and facilitated discussions about active learning. One faculty member was involved in the creation of a flipped classroom with a colleague, and the workshop enriched that work. For two faculty, their workshop experience created more contacts to discuss modules or teaching, but for most faculty interviewed, their teaching communities remained

local. The following quote from a geoscientist describes the importance of a temporary teaching community created at EER, and the tie to her local teaching community.

So, at the Rendezvous, I was able to get a lot of questions addressed and answered, and those are just valuable places to discuss ideas. I have a handful of faculty at other institutions that I talk to about things. There are a couple of people I contacted after the Rendezvous with specific questions related to things that I learned about there. But most of my - now that we actually have such a good community going locally - most of my quick conversations about teaching happen with my colleagues here.

Other collaborations mentioned by the unmentored faculty that resulted from their participation in workshops and webinars included:

- building new relationships with nearby 4-year institutions after meeting someone at an EER
- discussions with colleagues on broadening participation
- creating a PD with another faculty member from a different university around cognitive learning
- working on parts of a textbook in collaboration with a contact made at an EER

One geoscience faculty member credited her academic productivity and multiple collaborations to attending EER, saying, “I think I owe half of my career success to partnerships that have come out of it”. The following quote is a description of her collaborations.

The most long running one formed at the first Rendezvous, just from a conversation that was going on out in the hallway.... [Roughly] two years [...] later we published three papers together, submitted one grant together, and then we're working on two more papers. And we've launched one national survey, which is the basis for one of the papers. That's been the most productive with the collaborations that have come from it...and then there's several people who I collaborated with that came out of both the rendezvous and then GSA, who worked together on a research project...so we worked together to design teaching activities, and that several research studies have managed to get out on paper for grant applications and so on.

All faculty interviewed said they would continue participating in PD, in the form of webinars or workshops. Some appreciated the in-person work and connecting with colleagues, but others described their appreciation for webinars, as it did not take a lot of their time or require travel. Below is a quote from webinar-only faculty member, which was reiterated by other faculty.

I appreciate the webinars most of all. Not all of them work out time-wise, but the webinars afford me the opportunity to see whatever the latest resources are without having to travel. There's a balance there, because you don't get the face-to-face interaction and the connection that you do when you're physically located in the same place, but I think given the challenge of getting everybody together in a location ... I really appreciate the webinars.

The reasons unmentored faculty gave for wanting to continue PD included: staying current on topics; learning from “experts”; becoming a better teacher; helping students engage, be successful and learn; the fact it led to “measurable accomplishments”; and helping students see the connection between geoscience and society. The PD also served as a source of new ideas to use in the faculty’s own classes and to share with colleagues.

Departmental and Institutional Change

Webinar-only participants did not report any departmental or institutional changes. Two EER faculty saw an increased use of active learning techniques in their departments, and also observed several colleagues using InTeGrate materials in their classes. Two other EER faculty described an institutional leadership and administrative push towards utilizing “high-impact practices” and improving undergraduate pedagogy. The EER participants described InTeGrate as a tool used to accomplish those goals.

Other cross-disciplinary impacts included the creation of a new Honors program with an interdisciplinary focus that will be using InTeGrate. Below is a quote from a faculty member who is located outside of the geosciences.

So, I just finished designing our new staff honors curriculum, which will actually stand outside of the sciences, but the way that I designed the program is to emphasize interdisciplinary problem solving. It is like the core of the honors program, and one of the ways we will be doing that is I'm going to be having all of the honors faculty across disciplines use InTeGrate modules.

For another faculty member, as his institutional mission changes, he felt the InTeGrate resources allowed him to make changes to his classes without engaging in a time-consuming curriculum redesign. A final faculty member described the proposal of future courses around grand challenges that could incorporate InTeGrate materials.

Barriers

The barriers to impact appeared to be related to time, fit, and funding. The constraints for continued incorporation of InTeGrate's materials and pedagogy into faculty teaching and continuing collaboration in teaching communities centered around time and the need to balance other work priorities, such as research and service obligations, grant writing, class load, and administrative duties. Funding for travel to workshops and conferences was a barrier for some faculty. One faculty member also discussed technology as a potential barrier, observing that,

the only limitation that we would have with InTeGrate is just technology issues. I mean, something as simple as which browser a student uses, whether they're using a smart phone or computer; Mac or laptop.

For another faculty member, scaling the curriculum to larger classes and the time investment to design the adaptation was a barrier to implementation.

Conclusions

Overall, InTeGrate received positive feedback from faculty who had a wide variety of experiences and investment in creating or incorporating InTeGrate materials and being part of a greater teaching and learning community. Opportunities for interdisciplinary collaboration around curriculum, for improving teaching, and for building teaching communities were valued, and many faculty expressed their hope that these activities will continue.

Due to the time-consuming nature of curriculum development, many faculty noted that the existence of InTeGrate material enabled them to make changes in their courses. It also helped facilitate conversations about module material, curriculum, and teaching methods and in some cases, facilitated larger departmental or institutional changes focused on sustainability or active learning.

Faculty were also asked to describe how their activities related to InTeGrate's five guiding principles. The findings provide a strong endorsement for them. Across all groups the guiding principles were found to influence teaching content or assessment. Addressing *interdisciplinary problems* was the most universally mentioned, followed by using *authentic data*, focusing on *grand challenges* and *systems thinking*. The other principle of *geoscientific thinking* was also mentioned, but not to the extent of the other principles.

The InTeGrate experiences facilitated teaching changes within in all three groups analyzed. The level of teaching change for faculty appeared to be influenced by their willingness to incorporate active learning techniques and interdisciplinary content. Pedagogical changes were often more applicable to all disciplines and courses than the module material itself. Thus, active learning techniques, new assessment techniques and guiding principles were more often applied to additional courses, beyond the ones created for or around a module. However, there were several faculty who used the InTeGrate website and found parts of different modules to use in multiple courses, and for a few all courses.

The analysis also indicates that InTeGrate served to help inspire interdisciplinary degrees, curriculum, and institution-wide changes around sustainability education. The InTeGrate experience also motivated some faculty and students to increase engagement with their local community (e.g. research local creek and make recommendations, discuss local air quality, teach science in the community). Several new relationships between higher education institutions were also attributed to InTeGrate experiences and the collaborations which they facilitated.

Appendix A

Interview Protocol for Material Development and Implementation Site + QUBES Participants

How question relates to goals of study and anticipated findings	Purposes	Protocol
<ul style="list-style-type: none"> Identifies what types of disciplines/programs were potentially impacted (out of field impacts) Baseline for pedagogical approaches prior to ITG – will help us to know whether they were already committed to ITG pedagogy/5 guiding principles prior to their involvement 	<p>Background (5-7 mins.)</p> <p>Understand context of individual Pedagogical and practices prior to InTeGrate work.</p>	<ol style="list-style-type: none"> What subjects (geoscience, general ed, teacher prep, environmental science, social science, engineering, or other) and types (lower or upper division, major or elective, discipline specific or interdisciplinary) of courses do you teach? What program or department do you belong to? Can you describe your average class day (choose class described above) prior to your work with InTeGrate/IP site and how it exemplified your approach to teaching? <p>Prompt: What are you trying to accomplish with students with this approach? What are your philosophical drivers to teaching?</p> <p>Prompt: Listen for teaching methods (Lecture, active learning). Assessment methods.</p>
<ul style="list-style-type: none"> Which type of anticipated faculty impact rises to the top in the respondents' mind and how do they characterize that impact 	<p>Teaching impact (5 mins.)</p> <p>What they took from the experience</p>	<ol style="list-style-type: none"> If one of your colleagues asked what aspect of your work with InTeGrate impacted you the most, what would you say?

How question relates to goals of study and anticipated findings	Purposes	Protocol
<ul style="list-style-type: none"> • Changes in pedagogy and content • Whether any of the 5 guiding principles come through in their unprompted response 	<p>Teaching impact (5-10 mins.) Change to pedagogy and practice due to participation</p> <p>Change in influencing science and society</p>	<p>4. If I were to sit in on a class of yours today, what changes would I notice, from a class before InTeGrate/IP site (question #2)?</p> <p>Prompts:</p> <ul style="list-style-type: none"> • Have your teaching methods changed? • Have you focused on ‘grand challenges’ or the intersection of societal issues and environmental issues? • Has the material you used changed? <ul style="list-style-type: none"> INTEGRATE MATERIAL <ul style="list-style-type: none"> ○ Do they use full modules? ○ Pieced together units from various modules? ○ Create own activities/ curriculum? • Has your student assessment changed? <p>Prompts: Do you feel these changes will continue?</p> <p>Prompts: Have the changes occurred in all of your classes or just some? If just some, why? What prevents use in all?</p>

How question relates to goals of study and anticipated findings	Purposes	Protocol
<ul style="list-style-type: none"> • Baseline for student learning outcomes • How they describe the influence of the 5 guiding principles on their practices when prompted 	<p>TEACHING IMPACT (5-10 mins.) Impact of 5 principles</p>	<p>5. Prior to working with InTeGrate what were some of the important skills you were trying to teach students in all of your courses?</p> <p>6. As you might recall, InTeGrate materials needed to meet five guiding principles, (address one or more grand challenges involving Earth and society, develop student ability to address interdisciplinary problems, improve student understanding of the nature and methods of geoscience and developing geoscientific habits of mind, make use of authentic and credible data to learn central concepts in the context of scientific methods of inquiry, and incorporate systems thinking), how have these principles influenced your teaching?</p> <p>Prompt: can you give an example/story of how one or all of these principles influences your work now?</p>

How question relates to goals of study and anticipated findings	Purposes	Protocol
<ul style="list-style-type: none"> • Characterize how they might use a community of practice related to teaching • Attribute ITG involvement to any collaborations • Influence of ITG at programmatic or institutional scale 	<p>IMPACT-COMMUNITY & OTHER (10-15 mins.)</p> <p>Change in community</p> <p>Impact of spheres of influence</p> <p>Barriers to spread</p>	<p>7. How, if at all, did your work with InTeGrate/IP site lead to new collaborations or conversations about teaching?</p> <p>Prompts: Have these collaborations continued overtime?</p> <ul style="list-style-type: none"> • How has your definition of your 'teaching community' changed overtime? • How has your participation influenced it? <p>8. Can you describe any changes in your program or institution that you could contribute to InTeGrate/IP site work?</p> <p>Prompt: What lead to these changes? If no changes, what barriers exist (ex. time, colleagues, institutional focus)?</p>
	<p>WRAP UP (5 mins.)</p>	<p>9. Will you continue to be involved in a community that focuses on earth education (or the intersection of science and society)?</p> <p>Why or why not? If so, what kind?</p> <p>10. Is there anything I haven't asked about that you would like to share?</p>

Appendix B

Interview Protocol for Webinars and Professional Development Participants

Purposes	Protocol
Background (5-7 mins.) <ul style="list-style-type: none"> Identifies what types of disciplines/programs were potentially impacted (out of field impacts) Baseline for pedagogical approaches prior to ITG – will help us to know whether they were already committed to ITG pedagogy/5 guiding principles prior to their involvement Which type of anticipated faculty impact rises to the top in the respondents mind and how do they characterize that impact 	<ol style="list-style-type: none"> What subjects (geoscience, general ed, teacher prep, environmental science, social science, engineering, or other) and types (lower or upper division, major or elective, discipline specific or interdisciplinary) of courses do you teach? What program or department do you belong to? What InTeGrate PD or webinars have you participated in? Can you describe them? Prompt: What did you take away from those experiences? What motivated you to participate? Can you describe your average class day (choose class described above) prior to your Webinar/PD and how it exemplified your approach to teaching? Prompt: What are you trying to accomplish with students with this approach? What are your philosophical drivers to teaching? Prompt: Listen for teaching methods (Lecture, active learning). Assessment methods

Purposes	Protocol
<p>Teaching impact (5-10 mins.)</p> <ul style="list-style-type: none"> • Changes in pedagogy and content • Whether any of the 5 guiding principles come through in their unprompted response 	<p>4. If I were to sit in on a class of yours today, what changes would I notice, from a class before Webinar/PD (question #3)?</p> <p>Prompts:</p> <ul style="list-style-type: none"> • Have your teaching methods changed? • Have you focused on ‘grand challenges’ or the intersection of societal issues and environmental issues? • Has the material you used changed? • Has your student assessment changed? <p>Prompts: Do you feel these changes will continue?</p> <p>Prompts: Have the changes occurred in all of your classes or just some? If just some, why? What prevents use in all?</p>
<p>TEACHING IMPACT (5-10 mins.)</p> <ul style="list-style-type: none"> • Baseline for student learning outcomes • How they describe the influence of the 5 guiding principles on their practices when prompted 	<p>5. Prior to working with InTeGrate what were some of the important skills you were trying to teach students in all of your courses?</p> <p>6. The InTeGrate materials needed to meet five guiding principles, (address one or more grand challenges involving Earth and society, develop student ability to address interdisciplinary problems, improve student understanding of the nature and methods of geoscience and developing geoscientific habits of mind, make use of authentic and credible data to learn central concepts in the context of scientific methods of inquiry, and incorporate systems thinking), how, if at all, have these principles influenced your teaching?</p> <p>Prompt: Based on your InTeGrate professional development was there one of the guiding principles that stood out for you? Can you elaborate?</p> <p>Prompt: can you give an example/story of how one or all of these principles influences your work now?</p>

Purposes	Protocol
IMPACT-COMMUNITY & OTHER (10-15 mins.) <ul style="list-style-type: none"> • Characterize how they might use a community of practice related to teaching • Attribute ITG involvement to any collaborations • Influence of ITG at programmatic or institutional scale 	<p>7. How, if at all, did the Webinar/PD lead to new collaborations or conversations about teaching?</p> <p>Prompt: Have these collaborations continued overtime?</p> <p>How has your definition of your ‘teaching community’ changed overtime? How has your participation influenced it?</p> <p>8. Can you describe any changes in your program or institution that you could contribute to your webinar/PD work?</p> <p>Prompt: What lead to these changes? If no changes, what barriers exist (ex. time, colleagues, institutional focus)?</p>
WRAP UP (5 mins.) <ul style="list-style-type: none"> • Continued influence 	<p>9. Will you continue to seek out PDs/webinars on earth education (or intersection of science and society)? Why or why not? If so, what kind?</p> <p>10. Is there anything I haven’t asked about your experience that you would like to share?</p>