



InTeGrate: Interdisciplinary Teaching about Earth for a Sustainable Society

FINAL EVALUATION REPORT

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This report is available online at: https://serc.carleton.edu/integrate/about/project_products.html



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Chapter 1: Introduction

Organization of this report

This Introductory chapter opens with a high level statement of the goals of InTeGrate, the context in which it worked, and what problems it set out to solve. This is followed by a description of InTeGrate's program elements, how they interacted, and the activities that each undertook. A schematic diagram of program elements, a project chronology, and definitions of terms and acronyms are provided to help orient the reader to this complicated enterprise.

The three central data-rich chapters of the report lay out a set of claims about what InTeGrate accomplished and the evidence supporting each claim and subclaim. The three claims are that: (1) Teaching about the Earth has improved in pedagogy and relevance under the influence of InTeGrate, (2) InTeGrate has expanded the reach of high-quality Earth education opportunities, and (3) InTeGrate has contributed to the growth of a robust Community of Practice, which has the potential to carry InTeGrate's impact into the future.

The fifth and final chapter sets forth ideas about why InTeGrate was able to accomplish so much.

Context, Goals and Vision of InTeGrate

InTeGrate was co-funded by the National Science Foundation's Directorate for Education and Human Resources and Directorate for Geosciences, as a Center under the STEM Talent Expansion Program (STEP).¹ This funding was part of the American Recovery and Reinvestment Act of 2009, the stimulus package enacted by Congress following the Great Recession of 2008, and signed into law by President Barack Obama in February 2009.

The solicitation invited a "group of faculty representing a cross section of institutions of higher education to identify a national challenge or opportunity in undergraduate education...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." All STEP Centers were to be designed to "have a national impact on increasing the number of students... enrolling in undergraduate courses in STEM, and to improve learning and retention in those courses..." This was to be accomplished by developing, evaluating, and disseminating educational materials, teaching methods, and/or professional development.

For proposals in geoscience, the solicitation further required a focus on "essential concepts in Earth System Science and its foundational importance in areas such as the interplay of environment, energy, and economics." The emphasis on human/environment interactions continued with mention of grand challenges such as global climate change, contaminated and depleted fresh water systems, depleted energy and mineral resources, ocean acidification, declining fish stocks, and loss of biodiversity. The solicitation stressed the need to reach not just geoscience majors or STEM majors, but also "students majoring in economics, business, finance, urban planning, political science and other programs."

A multi-institutional proposal team, led by Cathryn A. Manduca of Carleton College, took on this challenge, with a proposal entitled "InTeGrate: Interdisciplinary Teaching of Geoscience for a Sustainable Future."² The proposal took the position that "The United States needs to build robust

¹ Science, Technology, Engineering, and Mathematics Talent Expansion Program Centers (STEP Centers). Program Solicitation NSF 10-569: <https://www.nsf.gov/pubs/2010/nsf10569/nsf10569.htm>.

² Project Summary is here: https://serc.carleton.edu/admin/private_download.php?file_id=28705 [Restricted access]. NSF Award Summary is here: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1125331&HistoricalAwards=false. Later in the project, the "tagline" was changed to "Interdisciplinary Teaching about Earth [rather than 'of Geosciences'] for a

educational pathways for its citizenry to develop the global perspective, cultural sensitivity, economic wisdom, and scientific acumen to inform their actions and address these grand challenges. The geosciences (marine, Earth, and atmospheric sciences) that explain the workings of the Earth system provide critical insight into all of these challenges and, consequently, must be firmly integrated into those educational pathways.” To this end, the proposed Center would work towards two goals: (1) to develop curricula that will dramatically increase geoscience literacy of all undergraduate students, including the large majority that do not major in the geosciences, those who are historically under-represented in the geosciences, and future K-12 teachers, such that they are better positioned to make sustainable decisions in their lives and as part of the broader society, and (2) to increase the number of majors in the geosciences and associated fields by developing and implementing cross-disciplinary programs as educational models that could be adopted or customized at other colleges and universities.

The InTeGrate Leadership Team envisioned a community-based approach grounded in the principles of participatory design:³ “By engaging more than 150 educators from diverse institutions across the country in the development and testing of materials, strategies and program models, we ensure that the materials will be valuable and adaptable for use in the full range of instructional settings and appropriate for a diverse range of students.” The proposal asserted that building many collaborative teams with participants from institutions across the country would “provide a natural foundation for dissemination and adoption of materials and methods,” helping to overcome institutions’ and faculty’s “cautious approach to changes in curriculum.”⁴ The Science Education Resource Center (SERC) at Carleton College was proposed as the technical and managerial hub for the distributed work, and was the lead institution on the proposal.

Program Elements

In order to accomplish these goals and achieve this vision, the InTeGrate team proposed three major program elements: Materials Development, Implementation Programs, and Professional Development. These were designed with intentional synergies, such that the products of one activity provided inputs into other activities. These three front-line program elements were supported by three behind-the-scenes elements: Assessment, Program Management/coordination, and Program Evaluation. The relations among these 6 program elements are shown schematically in Exhibit I-1, and each program element is described below. For each element, quotations from the proposal (in italics) convey the original vision for that element, followed by observations on how the element developed in practice.

Materials Development

*The first element of InTeGrate is to develop a new class of teaching materials that can be utilized in general education courses, core courses within geoscience majors, and courses designed for other majors including environmental studies, social science, engineering, and other sciences. These materials will be designed to: (1) develop geoscience literacy in a broad array of students; (2) emphasize the process of science; and (3) build interdisciplinary problem-solving skills that connect Earth science with economic, societal and policy issues throughout the curriculum.*⁵

Sustainable Future.”

³ Mao, J.Y., Vredenburg, K., Smith, P.W., Carey, T. (2005). The state of user-centered design practice. *Commun. ACM* 48(3), 105–109. Schuler, D. and Namioka, A. (Eds.) (1993). *Participatory design: Principles and practices*. Hillsdale, NJ, US: Lawrence Erlbaum Associates, 319 pp.

⁴ The proposal credited elements of this plan to several earlier effective programs, including *Project Kaleidoscope* (community problem solving), *On the Cutting Edge* and *Building Strong Departments* (community problem solving plus web-based sharing of materials and ideas), the *SENCER* project (community development and dissemination of curriculum modules) and *COMET*, *ESSEA* and *DataStreme* (nationwide online delivery of curricula.)

⁵ Italicized text in this chapter is from the InTeGrate proposal.

This element was extensively explored in the mid-project evaluation report,⁶ which described InTeGrate's strategy for developing curriculum materials and its beneficial impacts on the faculty involved. In brief, curriculum materials were created⁷ by teams of 3-5 faculty members from different institutions, who received stipends for their work. In most cases, development team collaborators were from different types of institutions and different disciplines. Teams created either one module, comprising 2-3 weeks of instruction, or one course, comprising a full term of instruction. Modules and courses include instructors' materials, student materials, and assessments, and were designed for web-publication. Design of the materials was guided by the InTeGrate Materials Development and Refinement Rubric,⁸ which specified 5 guiding principles (all of which had to be met), plus additional guidelines for effective student-centered pedagogy (most of which had to be met). The InTeGrate Assessment Team⁹ and SERC staff supported developers in their work, and the Assessment Team judged when each module or course had "passed the rubric" and was ready for pilot testing.

After passing the rubric, each course or module was pilot tested in at least 3 courses at different institutions. In most cases, the pilot testers were the faculty-developers, but in a few cases the developers were not able to test in a timely fashion, and another faculty member tested the materials instead. Developers/testers submitted several rounds of reflections on the development and testing process, culminating in a published "Instructor Story."¹⁰ Testers were required to obtain IRB approval for data collection, and then collect and submit a standard suite of student data (GLE, IAI, two essays, and embedded or summative assessments) from their pilot test class. The appropriate Assessment Team member(s) reviewed the student data and instructor's reflections, and worked with the development team to plan revisions. Development teams completed the agreed-upon revisions, and then worked with SERC staff to finalize the materials into a shared publication template. The final steps before opening the materials to the public were a technical review to address issues such as potential copyright violations and broken links, and a science review by content specialist(s). Developers were responsible for making revisions from these reviews, but were not required to re-test the materials after revision.

The first Materials Development Teams began their work in May 2012, and the last course was published in January 2018. In all, 26 free-standing modules and 6 full courses were developed, tested and published.

⁶ Kastens, K. A., Baldassari, C., and DeLisi, J. (2014). InTeGrate: Interdisciplinary Teaching of Geoscience for a Sustainable Future: Mid-Project Evaluation Report. 66 pp.

⁷ For more on the materials development process, see: Creating Teaching Materials and Examples of their Use: https://serc.carleton.edu/integrate/about/teaching_materials.html; Egger, A., Bruckner, M. Z., Birnbaum, S. J., & Gilbert, L. A. (2019). Facilitating the development of effective interdisciplinary curricular materials. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 45-68.

⁸ For more on the Rubric, see: Working with the InTeGrate Materials Development and Refinement Rubric: https://serc.carleton.edu/integrate/info_team_members/currdev/rubric.html; Steer, D., Iverson, E., Egger, A., Kastens, K. A., Manduca, C. A., & McConnell, D. (2019). The InTeGrate materials development rubric: A framework and process for developing curricular materials that meet ambitious goals. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 25-43

⁹ Assessment Team members are listed here: https://serc.carleton.edu/integrate/about/assessment_team.html. For further description of Assessment Team role, see Working with your Assessment Consultant: https://serc.carleton.edu/integrate/info_team_members/currdev/assessment.html

¹⁰ Instructor stories are linked from here: https://serc.carleton.edu/integrate/teaching_materials/community_use/instructor_stor.html

Implementation Programs

Lasting change requires work at the department, program or institutional level... Programs must promote student motivation and enthusiasm for studying geoscience; provide academic supports for students in the form of strong curricula, supporting services, and co-curricular activities; and cultivate a sense of belonging both within their program of study and in the larger professional community that they will enter... InTeGrate will support a series of implementation programs to develop bold approaches ... designed to reach a diverse array of students, including those from groups underrepresented in the geosciences and students whose dominant interest or field of study lies outside the geosciences.

Three of InTeGrate's Implementation Programs (IPs) were designed into the proposal and began their work early in the project; thirteen others were chosen by a competitive application process¹¹ during project years 3 and 4. Across three rounds of open solicitations, teams from institutions or clusters of institutions were invited to compete for \$50,000 grants from the InTeGrate project. Solicitations encouraged applicants to make use of InTeGrate-developed materials, model innovative ways to increase the numbers of students developing geoscience literacy, and contribute to the preparation of a workforce equipped to bring geosciences to bear in solving societal issues. The selected teams represented a wide array of approaches, customized to the needs and strengths of their constituency. Each team was required to develop an evaluation plan that would document the IP's progress towards meeting that IP's specific goals.

Professional development for IP team members around programmatic change was provided via webinars and web materials.¹² Each IP team was required to track their progress on the internal InTeGrate website in a common format, documenting their program goals, actions they had taken to achieve those goals, concrete evidence of progress towards the goals, evidence-supported impacts their work had on teaching and learning, key aspects of the implementation that the team thought contributed to observed successes, unexpected outcomes, and anticipated next steps. As each IP grant wrapped up, public websites were published as "program models," sources of ideas that other institutions could draw on to tackle similar challenges or goals.¹³

Although the IPs had emerged in different settings in response to different needs and had thus taken quite different forms, the project worked hard to extract overarching lessons learned from the IP portfolio. At the beginning of project year 6, immediately after the deadline for publishing program models, representatives from all IPs were brought together for a Synthesis Workshop.¹⁴ Working in small cross-IP groups, workshop participants pooled their collective experience and articulated what they had learned around the themes of 'Recruit and support diverse learners,' 'Teach Earth across the curriculum'

¹¹ In the first round of IP proposals, decisions were made by a subset of the InTeGrate Leadership Team with selected members of the Advisory Board. In subsequent rounds, the review panel added members from the National Association of Geoscience Teachers (NAGT). Source: email, C. Manduca, July 30, 2019.

¹² In the early years of the project, some workshops were designed to gather insights and tools for affecting program-scale change, and SERC staff then shaped these materials into websites for the use by IP teams. For example, the first InTeGrate workshop, on *Programs that Bring together Geoscience and Sustainability* (<https://serc.carleton.edu/integrate/workshops/programs2012/index.html>) supported the development of a website on *Common Structures for Interdisciplinary Programs* (https://serc.carleton.edu/integrate/programs/embed_sustainability/common_structures.html)

¹³ All 16 program models are linked from: <https://serc.carleton.edu/integrate/programs/implementation/index.html>

¹⁴ Website for Implementation Teams Synthesis Workshop: <https://serc.carleton.edu/integrate/programs/implementation/2016synthesis/index.html>. The cross-program synthesis workshop technique had been previously used in the SERC-supported project on Supporting STEM Success in a Liberal Arts Context: <https://serc.carleton.edu/liberalarts/index.html>.

‘Prepare teachers to teach Earth Science,’ ‘Support transitions to workforce/transfer/career,’ and ‘Make and sustain change on our campuses.’ This synthesis was published on the website and illustrated with examples from specific program models.¹⁵

Professional Development

The activities within the professional development program will cultivate connections among individuals with this expertise and foster their ability to learn from one another and work together to address the challenges they face individually and collectively. Professional development programming will capitalize on web resources, face-to-face workshops and virtual activities... and will make full use of the SERC infrastructure... Topical workshops will explore current practices and their strengths and weaknesses... Program level workshops will focus on identifying successful models for interdisciplinary instruction and programming..., broadening access to geoscience..., and new programs ...that focus on preparing students to address sustainability... In later years, we will move towards disseminating materials, models and lessons learned... A visiting workshop program will ... bring... teams of two leaders to work with groups of faculty on campus... Virtual events will support successful adoption and adaption of materials and models...

Workshops: InTeGrate began its work with a very strong heritage of effective professional development workshops for higher education faculty in geosciences. The *On the Cutting Edge* program had ten years of experience running topical workshops that attracted faculty from across the country to a central location to learn from each other and from expert facilitators about how to tackle a specific pedagogical challenge (e.g. Teaching Structural Geology in the 21st Century). The *Building Strong Departments* program expanded the workshop strategy to challenges at the scale of a program rather than an individual course (e.g. Successful recruitment of Geoscience majors).¹⁶ These programs were coordinated through SERC, and developed a methodology in which SERC’s web-based Content Management System (Serckit) was used to capture, share, archive, organize and then disseminate insights emerging from a highly-interactive workshop format. Many of the founding leaders of InTeGrate were veterans of these earlier programs, and the synergistic workshop/website methodology was carried over in its entirety into the InTeGrate project. Throughout its lifespan, InTeGrate hosted 36 face-to-face workshops, almost all of which produced web products for use by the broader community (Exhibit IV-1). InTeGrate’s workshop program branched outward from its roots in physical Earth Systems to encompass topics of concern to broader communities as well as topics at the interface between human systems and Earth systems.

Traveling Workshop: The *Building Strong Departments* programs had also developed a Traveling Workshop Program,¹⁷ in which skilled facilitators—who were themselves geoscience faculty—led multi-day, on-campus workshops to support conversation, planning, and reform by departments or programs as a whole. Under InTeGrate, the Traveling Workshop program was expanded to encompass new sustainability, teacher education, and diversity themes, and the leadership corps was enlarged and

¹⁵ SERC staff compiled the lessons learned into web pages linked from:
<https://serc.carleton.edu/integrate/programs/implementation/index.html#synthesis>

¹⁶ Building Strong Geoscience Departments: Workshops:
<https://serc.carleton.edu/departments/workshops/index.html>. Also, Manduca, C., H. Macdonald, and G. Feiss (2008). Education: Preparing Students for Geosciences of the Future, *Geotimes* 53(4), p. 59.
<http://www.geotimes.org/apr08/article.html?id=comment.html>. Manduca, C.A. (2008). Working with the Discipline - Developing a Supportive Environment for Education. Commissioned paper presented at the National Research Council’s Workshop Linking Evidence to Promising practices in STEM Undergraduate Education, Washington D.C. Available at: http://sites.nationalacademies.org/cs/groups/dbasseite/documents/webpage/dbasse_072635.pdf

¹⁷ Traveling Workshops Program: <https://nagt.org/nagt/profdev/twp/index.html>

diversified. This program will be sustained in the post-InTeGrate era under the National Association of Geoscience Teachers (NAGT) professional development program.

Earth Educators' Rendezvous: Beginning in 2015 (project year 4), InTeGrate, in collaboration with the pre-existing *On the Cutting Edge* project and the National Association of Geoscience Teachers, consolidated much of its face-to-face professional development effort into a new week-long annual event, the *Earth Educators' Rendezvous*.¹⁸ The Rendezvous format is highly interactive with many opportunities for attendees to contribute on a small scale (e.g. a poster or a teaching demo) or large scale (e.g. convening a workshop), and with many opportunities to forge connections and collaborations. InTeGrate content is a strong thread running through the Rendezvous, but other projects have now adopted the Rendezvous as their gathering point: the 2019 program includes morning or afternoon workshops organized by half a dozen other major education initiatives.¹⁹ The Rendezvous is now under the leadership of NAGT and is financially self-sustaining. Attendance at Rendezvous has ranged from approximately 233 to 342 participants, and July 2019 marks the fifth annual such event.

Webinars: The proposal made very brief mention of “virtual events” as support for InTeGrate’s other activities. But during the InTeGrate timeframe, both the technology for supporting virtual convenings and the community’s comfort with such events improved, and webinars grew into a major component of InTeGrate’s professional development effort. Webinars ran at the rate of approximately one per month,²⁰ serving both as professional development for the faculty presenters and attendees, and as a dissemination mechanism for InTeGrate materials and models.

Website: InTeGrate built an extensive public website, which was redesigned several times as new content became available, in an effort to make it easier for users to find resources or ideas that would be useful to them. The focus of the public website was on actionable insights and resources, summarized on the *Intro to InTeGrate* page as: classroom-ready peer reviewed teaching activities you can adapt to use in your existing courses, guidance on catalyzing sustainability education on your campus, and access to a community engaged in sustainability education.²¹ By Spring 2019, the website was welcoming 26,000 unique visitors per month.

Designed Synergies between Program Elements

Multiple synergies were designed into the InTeGrate system, with the idea that each program element would both draw from and support other program elements, creating a virtual cycle such that the whole could be greater than the sum of its parts. Exhibit I-1 maps a few of the large-scale flows of information and influence between major program elements. Many other flows and influences are mapped in Kastens, et al. (2014) and Kastens & Manduca (2017).²² Arrows in Exhibit I-1 indicate:

¹⁸ Earth Educators' Rendezvous: https://serc.carleton.edu/earth_rendezvous/index.html. The heritage of the Rendezvous includes large annual summer workshops that were organized by the Digital Library for Earth System Education (DLESE) in the early 2000's.

¹⁹ Future of Undergraduate Geoscience Education Heads and Chairs meeting; Preparing for an Academic Career workshop; GETSI; GEODE; Data Labs from the Ocean Observatory Initiative; MATLAB.

²⁰ InTeGrate workshops and Webinars: <https://serc.carleton.edu/integrate/workshops/index.html>

²¹ An Introduction to InTeGrate: https://serc.carleton.edu/integrate/itg_intro.html

²² Kastens, K. A., Baldassari, C., and DeLisi, J. (2014). InTeGrate: Interdisciplinary Teaching of Geoscience for a Sustainable Future: Mid-Project Evaluation Report. See systems maps in the Appendix, available at: http://d32ogoqmya1dw8.cloudfront.net/files/integrate/about/integrate_mid-project_evaluati.pdf. Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230.

- Materials Development → Implementation Programs: Instructional materials created by InTeGrate module/course development teams were adopted or adapted by almost all of the IPs.
- Implementation Programs → Materials Development: Needs perceived by IP leadership inspired some materials development efforts. For example, IPs with a goal of broadening participation in Earth education created a desire for instructional materials that attended to issues of environmental justice.
- Assessment → Professional Development: Early responses coming in from the materials rubric audit process and from student assessments helped to shape the professional development program for both materials developers and instructors. For example, one of the first findings from the Assessment Team was that materials and student work were weak on systems thinking. As a result, the professional development program spun up webinars, web content, and a dedicated student module on systems thinking.
- Professional development → Implementation Programs. Early professional development workshops had as an explicit goal to gather resources and ideas that would feed into program-level reform or improvement, and to bring together colleagues who might coalesce into IP teams. For example, the 2012 workshop on Teaching the Methods of Geoscience resulted in web content that supported all of the teacher prep oriented IPs.

Assessment

The Assessment Team ... will take a two-fold approach to assessing the quality of materials and courses. First, they will work with module and course developers to make sure that all materials are aligned with the project goals and are designed on the basis of research on learning. ...A rubric will be used to assess if the materials are likely to be effective ... Only when materials pass the initial development phase will they be piloted in classrooms... Second, the assessment team will focus on measuring the impact of materials on student learning. They will guide the development teams in embedding assessments ... [and] in making use of appropriate summative measures that will allow us to measure the impact of materials across the project. ... The assessment team will select from and build on these instruments to create a suite of measures that specifically address the project goals of increasing students' geoscience literacy, understanding of the process of science, and interdisciplinary problem solving ability... Data will be collected as materials are piloted and submitted using an online system on the SERC website.

The Assessment Team of about dozen faculty members from institutions across the country were either recruited by invitation or chosen through a competitive application process.²³ Members were selected with expertise in both geoscience and student learning assessment. They met once per year face-to-face and multiple times per year virtually. They were supported by virtual collaboration tools, both off-the-shelf and purpose-built by the SERC technical staff. The team was led by David Steer, Ellen Iverson, and Stuart Birnbaum.

The Assessment Team developed the rubric that guided Materials Development Teams and was used to judge whether materials were ready to be pilot tested (see above under “Materials Development”). As each Materials Development effort got underway, a member of the Assessment Team (the “Assessment Consultant”) provided formative feedback across a series of checkpoints to help the teaching materials meet the InTeGrate standards and to ensure they supported the stated learning goals for the

²³ Procedure confirmed by Ellen Iverson, July 2, 2019, based on her review of contemporaneous emails. Recommendations for invited AT members were solicited from Leadership Team and from NSF program officers.

course or module. The assigned Assessment Consultant plus one or two other members of the Assessment Team then judged whether the course or module was ready for pilot testing.²⁴

Finding no existing assessments that matched InTeGrate's goals, the Assessment Team developed and tested its own suite of student assessments:²⁵ The GLE or Geoscience Literacy Exam is a short-answer test of fundamental scientific knowledge about climate, oceans, atmosphere and solid Earth.²⁶ Two short essay questions probed students' basic grasp of interdisciplinary problem solving and systems thinking. In addition, the Assessment Team coached materials development teams in creating embedded assessments, both formative and summative, which would gauge students' progress towards learning goals specific to that module or course. The Assessment Team also collaborated with the Evaluation Team in developing the IAI or InTeGrate Attitudinal Instrument, an online survey that collected students' demographic information and probed their career interests and motivation to contribute to solving environmental problems.

During pilot testing, this entire suite of student assessments (GLE, two essays, summative assessments, and IAI), as well as a syllabus and student roster, was expected from every developer/tester. As data came in from a pilot test, the assessment consultant digested the data and met with the development team to reflect on what had gone well and poorly in order to create a plan for revisions.

Working collaboratively, the Assessment Team also looked across the project, as a whole, at data from the GLE, a sampling of responses from embedded²⁷ assessments, and a sampling of responses from each essay question. Based on such multi-module analyses at various stages of the project, the Assessment Team recommended additional professional development for materials development teams, additional scrutiny of specific rubric elements during the pre-pilot-testing phase, revision and re-revision of the systems thinking essay, and other formative improvements to the in-progress project.

Program Leadership, Management, Coordination and Infrastructure

We propose a management structure where senior personnel... are assigned clear leadership for specific segments of the program; while support for this leadership team, website, and professional development is centralized at SERC... This model ... has the advantage that faculty from across the country can be engaged in leadership of the program and its activities while the program as a whole has a central communication structure, strong project management (including timelines), and a unified public face.

InTeGrate was led by Cathy Manduca of the Science Education Resource Center (SERC) at Carleton College. A petrologist and field geologist by training, Manduca has spent most of her career in

²⁴ Procedure confirmed by Ellen Iverson, July 2, 2019. Early in the project, two other Assessment Team members (besides the consultant) judged the material's readiness for testing. Later in the project one other AT member was considered sufficient, unless there was a specific reason to bring in a third AT member.

²⁵ See also Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O'Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp 91-119.

²⁶ The earliest versions of GLE also included essay items that probed higher cognitive levels for each geoscience literacy big idea. These items were made available to materials developers and were used by some teams. However, the 8-item version of GLE which was used by the project wide assessment, and the 16-item version used by the Research Team, were short answer only.

²⁷ Early in the project, the Assessment Team (AT) looked at student responses to formative assessment questions that were interspersed throughout the module and chosen by the materials developers/testers. Later in the project, the AT required the testers to submit student responses to summative assessments that could demonstrate student mastery of the module or course learning goals.

science education leadership and reform, first at the Keck Geology Consortium, and then as the founding director of the SERC at Carleton College. Concentrically outwards from Manduca was a group of four co-PI's (Exhibit I-2), who collectively brought expertise in education research, online education, teacher preparation, diversity/inclusion, and several different branches of geosciences. Concentrically outwards from them was a larger Leadership Team, which brought additional expertise in assessment and evaluation, environmental education and ecology, education at minority-serving institutions, education at 2YC's, as well as collaborative links to various cooperating organizations.

As anticipated in the proposal quotation above, each Leadership Team member had specific areas of responsibility (Exhibit I-2). They coordinated through quarterly meetings (3 virtual and 1 face-to-face per year), and voluminous list-server email, and via password-protected work areas on the InTeGrate website. Non-SERC members of the Leadership Team were compensated for their work, at the level of 1-2 months of salary per year, through subawards. All of the PI's and 8 other members of the Leadership Team stuck with the project from beginning to end. Two members of the initial Leadership Team withdrew over the course of the project, and four new members were added to fill the responsibilities of those who left and to cover newly-identified responsibilities.

InTeGrate had an engaged and accomplished Advisory Board (Exhibit I-3). The Advisory Board brought a wealth of experience and expertise in leadership of large education programs and reform of science education. Physics, chemistry, life sciences, geography and environmental science education were represented, opening the door for insights and lessons learned to flow both to and from education reform efforts in other disciplines. In keeping with InTeGrate's workforce preparation / talent expansion goals, the Advisory Board included individuals from industry and government service, as well as academia. The Advisory Board met once per year, face-to-face. Meeting time was approximately evenly split between updates/presentations, and in-depth discussions of specific high-level challenges and opportunities. Between meetings, individual Board members were occasionally tapped as reviewers or mentors for various parts of the project.

The SERC office at Carleton College, Northfield, Minnesota, provided multiple forms of supporting services.²⁸ On the business side, SERC dispersed and monitored use of NSF funds, including administering dozens of subawards with Leadership Team members, Materials Developers, Assessment Team members, and Implementation Program teams. As event organizers, SERC staff organized venues, logistics, outreach, and technical infrastructure (e.g. project team websites) for scores of face-to-face events and hundreds of virtual events. SERC staff developed expertise in marketing and outreach, and served as technical editors for all of InTeGrate's outward facing content, including instructional materials. In addition, much of the synthesizing of web content (content which combines input from multiple events or sources) was written by SERC staff, who assembled coherent presentations for the public from the brainstorming and discussion notes from faculty, collected at workshops and other meetings, leavened by insights from the literature. As described below, InTeGrate fostered a project-wide culture of evaluation, in which faculty across the country played roles in collecting, analyzing and interpreting student data from more than 100 campuses. SERC operated a *de facto* assessment and evaluation consulting service, mentoring project members in everything from how to set measurable goals, to how to write an IRB application, to what statistical approach to take in analyzing student data.

The final component of the SERC-based support system is the InTeGrate website. The Serckit web-based Content Management System²⁹ was used extensively throughout the InTeGrate ecosystem: to capture ideas and information emerging at workshops and meetings, to publish subaward work products,

²⁸ Key SERC support personnel are profiled here: <https://serc.carleton.edu/integrate/about/staff.html>. See also S. Fox, E. Iverson, and Cailin Huyck Orr, who are profiled on the Integrate Leadership Team page at: <https://serc.carleton.edu/integrate/about/leadership.html>

²⁹ Serckit: <https://serc.carleton.edu/serc/about/serckit.html>

including curriculum modules and program descriptions, and to disseminate syntheses of bodies of work, such as lessons learned from the IP programs. Behind the publically-available outward-facing web pages is a vast inward-facing web domain which contains work spaces for all the major InTeGrate subsystems, such as module development teams, IP teams, Assessment Team, Leadership Team, etc. All told, the outward-facing InTeGrate web domain constitutes >3,500 pages, and the inward-facing domain constitutes >1,400 pages.³⁰ InTeGrate's technical team designed and constructed many purpose-built digital tools for the project. These tools automated and regularized many repetitive processes, making it possible for InTeGrate to grow to scale and to document its accomplishments. Although these tools took many forms, perhaps the most enabling were tools that married digital databases with web-based input and output portals, for example the tool used by the Assessment Team to collaboratively score student essays, and the system by which diverse types of information from diverse teaching contexts was funneled into a master database of classroom use. SERC's Technical Director Sean Fox exhibited an exceptional ability to comprehend problems at a deep level, envision technical solutions, and then instantiate the solutions in a way that worked for college faculty users.³¹

Program Evaluation

Project evaluation will focus on the measurable impact on programming, the associated impact on student learning, and the ultimate impact on students' ability and willingness to engage in societal roles addressing the sustainability of our civilization and our environment.... Because the community-based project design depends critically on successful collaboration among partners who are dispersed by geography, discipline, and institution type, the external evaluation team will provide formative evaluation of the partnership and sub-partnerships...

It was a purposeful intention of the InTeGrate leadership to establish a pervasive evaluation culture out into the farthest tendrils of the project. Drawing on Preskill & Boyle's (2008) model of evaluative capacity building,³² InTeGrate used multiple strategies to build capacity, including communities of practice, involvement of individuals in evaluative processes, and coaching and assistance from an evaluation expert. The intent was that everyone involved with the project would continuously reflect upon the effectiveness of their teaching and learning efforts, sharing those reflections, and in some cases collecting and analyzing data pertaining to learning outcomes and teaching practices. At the student level, the Materials Development Rubric requires that instructional materials involve students in metacognitive reflections on their own learning and understanding. At the faculty level, materials development faculty became both collectors of student data, as well as reflection writers and subjects for classroom observations and surveys. At the programmatic level, Implementation Programs were required to design and implement an evaluation plan optimized for their own goals and context, and were given staff support to do so. As noted above, an Assessment Team, comprised of faculty from across the country, designed student learning outcomes assessments and analyzed the data coming in from them. The "Research Team" recruited faculty interested in learning more about education research, and then mentored them through the process of collecting and analyzing data on their own classes before and after adding InTeGrate content into their curriculum.³³ All this was in addition to the work of internal

³⁰ As of April 1, 2019, according to email from Sean Fox, SERC. (3579 public pages; 1436 private pages in workspaces).

³¹ Fox explains his approach here: <https://serc.carleton.edu/serc/sean.html>

³² Preskill, H., & Boyle, S. (2008). A multidisciplinary model of evaluation capacity building. *American Journal of Evaluation*, 29(4), pp. 443-459.

³³ Nagy-Shadman, E., Rivera, T., Berg, C., Abolins, M., Hansen, W., Nelson, D., Rademacher, L., and Richaud, M., (2018). Integrating InTeGrate: Faculty Assess Classroom Experience, *In the Trenches*, 8(4), 1-5. Online at: https://nagt.org/nagt/publications/trenches/v8-n4/integrating_integrate_faculty_.html.

evaluators within SERC as well as external evaluators at Columbia University, the Program Evaluation Research Center (PERG), and the University of Washington.

The result is a vast but uneven data set. Thus, this report can be metaphorically viewed as a quilt, in which many individuals and groups have crafted squares, and the evaluator/author of the report has stitched them into a whole.

There is an inherent tension in this approach. If one wants the best-documented, most internally-consistent, most accurate possible data, then it's problematic to let "amateurs" collect the data, and problematic to keep tweaking the intervention so that the assessment results come out better. On the other hand, what if one of the project goals is that those very same "amateurs" shall become deeply invested in the process of collecting and analyzing education data, and develop the habits of scholarship of teaching and learning? In that case, then having the participants plan and execute their own data acquisition and analysis can be a winning strategy. So, the imperfections of InTeGrate's data set have to be set against the gain of a nation full of Earth educators who now have increased capacity and motivation to research the effectiveness of their own teaching and the educational reforms they are trying. InTeGrate's bet is that long after this report is filed away and forgotten, a meaningful number of Earth educators impacted by InTeGrate will still be collecting and analyzing education data, and using the results to inform and improve teaching and learning among those around them.

Amidst all this dispersed activity, InTeGrate did have a team of internal and external evaluators explicitly focused on how well the project was progressing towards its goals. The division of labor among the evaluation team was as follows:

Kim Kastens of Lamont-Doherty Earth Observatory (Columbia University)³⁴ was with the project from the preliminary proposal stage through to the last page of this final report. She is an oceanographer by training, but with extensive experience in Geoscience Education Research. She was the author of the present report, with extensive help from SERC staff and the InTeGrate Leadership Team, and drawing deeply on the work of the other evaluators listed below. She attended all leadership team meetings, all Advisory Board meetings, all NSF site visits, four out of five Earth Educators' Rendezvous, dozens of webinars, many Assessment Team meetings, the IP Synthesis meeting, plus other assorted workshops and team meetings. She led the development of the InTeGrate Attitudinal Instrument (IAI) and analysis of data from that instrument, as well as the InTeGrate-focused analysis of the data from the 2016 NAGT National Geoscience Faculty survey.³⁵ She conducted hundreds of lightning interviews with Rendezvous attendees, seeking evidence of whether and how the event was helping to build community. Throughout the project, she sought ways to understand and communicate how InTeGrate functioned as a system, developing diagrammatic system maps, an analysis of how systems thinking shaped the design of InTeGrate, and a conceptual systems dynamic model of the geo-ed community of practice.

Carol Baldassari was with the project from funding day 1 (2011) until her retirement in 2017. She is an experienced program evaluator with the Program Evaluation Research Group (PERG).³⁶ She and PERG colleagues were instrumental in designing InTeGrate's evaluation program, and Baldassari co-authored the mid-project evaluation report. She did a series of interviews with project leadership and

³⁴ Kastens was a Lamont Research Professor at Lamont-Doherty from the project's start through Sept. 2012, then a Distinguished Scholar at Educational Development Center, Inc. through Dec. 2014, then a Special Research Scientist at Lamont-Doherty until the end of the project. Kastens was assisted by Jackie DiLisi at EDC, and by Margie Turrin and Valentina Mara at Lamont.

³⁵ NAGT National Survey of Geoscience Faculty website:
https://serc.carleton.edu/NAGTWorkshops/CE_geo_survey/index.html

³⁶ Program Evaluation & Research Group: <https://www.endicott.edu/about/research-at-endicott/perg>. From the beginning of the project until July 2013, PERG was at Lesley University; after that, the group moved to Endicott College. PERG colleague Sabra Lee also worked on the initial design of the evaluation plan, and on the IP study.

Materials Developers early in the project, documenting the effective spin-up of project working relationships and the value of the materials development process as professional development for the participating faculty. As the first cohort of competitively-selected Implementation Programs were becoming established, Baldassari studied six IPs through document analysis and interviews with IP leadership, examining their use of InTeGrate materials, strategies for engaging faculty and making program efforts visible, their challenges, and the fit between IP goals and host institutional goals.

Following Baldassari's retirement, SERC contracted with the University of Washington Community College Research Initiative for a final round of interview-based studies. *Debra Bragg, Lia Wezstein, and Katie Kovacich*, conducted 51 semi-structured phone interviews with faculty representative of three groups: materials developers, faculty who were mentored on InTeGrate's guiding principles (such as IP faculty), and individuals who participated in InTeGrate events (such as workshops) but did not have a mentor. Interviewees were asked about how InTeGrate had impacted their teaching, programs or institutions, the role of InTeGrate in fostering community, and any emergent impacts associated with participation in InTeGrate.

Frances Lawrenz of the University of Minnesota was an evaluation consultant for the project, providing outside guidance to the evaluation team. She met with the evaluation team during Year 3 to review work to date, provide input into the mid-project report, and help plan evaluation of the IP program. She met again with the full Leadership Team in project year 5 at an "evaluation summit," where the evidence was assembled and critiqued for what eventually became the claims and sub-claims of this report.

Whereas the evaluators above were at somewhat of an arm's length relationship to the project, *Ellen Iverson* is a SERC staff member and was considered an internal evaluator. She played a role in almost all aspects of InTeGrate assessment and evaluation. Among other things, she oversaw the survey-based evaluations of workshops, webinars and the Rendezvous; designed the strategy by which InTeGrate participants were categorized for analysis in the 2016 National Geoscience Faculty Survey; developed and led the administration of the implementation program faculty survey and the Reach surveys; developed the 3-tiered division of InTeGrate faculty for the final interview study; managed the work of the external evaluation team from University of Washington who conducted and analyzed these interviews; collaborated with this same interview team on analyzing the interviews, faculty reflection surveys, implementation program surveys, and reach surveys in terms of the "downstream" (longer-lasting) influences of their InTeGrate experience on faculty participants. In the complex ecosystem of InTeGrate, Iverson served as an essential connecting link among the external evaluators, the Assessment Team, and the SERC staff.

Chronology

Key members of the InTeGrate Leadership Team began work in early 2010, working towards a Letter of Intent submission in August 2010, a preliminary proposal submission in September 2010, and a full proposal submission in January 2011. Thus, by the end of the grant (November 30, 2019), this work will have spanned almost a decade. Funded work began on December 1, 2011. The project was originally scheduled to sunset five years later, but extended its work for three more years via two no-funds extensions, and a \$200K supplement for work by the HBCU Working Group.³⁷

A chronology of each year's activities is summarized in Exhibit I-4, broken into categories of Leadership, Administration & Infrastructure; Diversity & Inclusion; Materials Development; Implementation Programs; Professional Development; and Evaluation & Assessment. This timeline is intended to situate events relative to each other in time, to give future program planners a sense of how

³⁷ Summary of Proposed Work [in HBCU supplement]. Justification of Supplement. These project documents were provided by the SERC office.

long various efforts took, and to enable temporal reasoning about which developments may have caused or influenced subsequent developments. Exhibit 1-4 also gives a sense of how many things were happening simultaneously, and thus the leadership challenge in keeping many pieces moving forward simultaneously like the threads of a braided stream.

Exhibit I-4 also reflects the waxing and waning of activities over time. *Materials development (MD)* got off to a fast and early start with major landmarks in project years 1 and 2. MD continued to command substantial attention and resources into years 5 and 6, with the last lagging course finally published in year 7. The *Implementation Program (IP)* effort got off to a slow start, awaiting a critical mass of published instructional materials, leadership capacity, and a clearer vision of what this new entity called “Implementation Program” was supposed to be. The IP program got seriously underway in year 3, hit its full stride in years 5 and 6, and had tapered by years 7 and 8.

Professional development and evaluation/assessment efforts were substantial in every year, but evolved in character over time. In years 1 through 3, the main PD vehicle was small to medium face-to-face workshops, with travelling workshops joining the mix in year 3. Year 4 brought the first Earth Educators’ Rendezvous, and the launch of the webinar program. The public website grew in size and visitors with every passing year, with course-scale content dominating early on, and program-scale content growing in importance later on. *Evaluation and assessment* began with a heavy dose of instrument development in year 1. In years 2 and 3, the early student and faculty data were used simultaneously to tweak the suite of instruments and to provide formative feedback to material developers. Evaluation of IPs was formalized beginning in year 3, with the development of the IP faculty survey and procedures for coaching IP leadership teams through the process of crafting and executing evaluation plans. From year 4 onward, various components of a project wide evaluation gradually came into focus, based on a critical mass of student data, new rounds of interviews, and availability of the 2016 National Geoscience Faculty Survey as a comparison group.

Substantial leadership and staff time was invested in *diversity and inclusion efforts* in every year of the project, but these efforts did not really begin to take off until project year 4. Project years 5 and 6 were very strong years for diversity and inclusion efforts, with formation of the HBCU working group, three workshops explicitly designed around issues of concern to the HBCU community, more than 500 students per year reached by the El Paso area IP activities, and a total of ten IPs working on diversity as one of their goals. In years 7 and 8, as other program activities have been tapering, the diversity and inclusion efforts are still in full swing, as evidenced by: the 2019 Rendezvous being co-sponsored by and held at an HBCU, an HBCU Research Team collecting and analyzing student data from courses that adopted or adapted InTeGrate materials, the awarding of an NSF GeoPaths grant that built on InTeGrate ideas and collaborations, and the implementation of a successful and oversubscribed workshop on Diversity, Equity, and Inclusion in the Earth & Environmental Sciences.

Claims of Accomplishments and Evidence for Same

How the suite of claims was developed: The directive that InTeGrate’s end-of-project evaluation should be cast in terms of claims of accomplishment and evidence for same (as contrasted with activities conducted) was introduced by NSF program directors during a reverse site visit in November 2014 (end of project year 3). This resonated with an idea developed in the mid-project evaluation report (Fall 2014), that InTeGrate’s leadership should be thinking and planning in terms of “lasting traces” left on the landscape of education by the InTeGrate event, analogous to the lasting traces left on the Earth by an orogenic or climatic event. The external evaluation team assembled a hierarchal suite of claims and subclaims that InTeGrate might want to be able to make by grant’s end. At the time, these were called “proto-claims,” as many were still emergent, and it was not yet fully clear which subset of them would be supportable. At their Sept 2015 meeting (project year 4), the Advisory Board engaged in an interactive exercise to vet and improve the set of proto-claims, bringing forth many ideas for inclusion, exclusion, modification, and evidence-gathering about various potential subclaims. At the reverse site visit of

October 2015, four proto-claims were presented to NSF program officers, who conveyed NSF's prioritization among them. In May 2016, the leadership team and evaluation team conducted an Evaluation Summit, at which the existing evidence in support of each of the candidate proto-claims was scrutinized. Gaps in evidence were identified, and plans to fill key gaps were developed. Weak or peripheral claims were dropped. External evaluator Kastens assembled the claims and evidence into Chapters 2, 3 and 4 of this report, supported by the SERC staff. Each chapter was reviewed by one or more members of the leadership team, and by project PI Manduca.

Out of this process three big claims emerged,³⁸ each broken down into several sub-claims and multiple sub-sub-claims:

Claim 1: Teaching about the Earth has improved in pedagogy and relevance under the influence of InTeGrate: This claim covers InTeGrate's instructional materials, as well as impact on faculty and students who were touched by InTeGrate. With respect to materials, both the system for collaborative development of instructional materials and the attributes of materials themselves are put forward as accomplishments. With respect to faculty, the claim addresses shifts by faculty towards research-tested pedagogies and towards teaching about the Earth in the context of societal problems. With respect to students, Claim 1 covers the system for nationwide, collaborative assessment of student learning, as well as increases in student geoscience literacy, interest in Earth-related majors and careers, and motivation to contribute to solving Earth-related problems.

Claim 2: InTeGrate has expanded the reach of high-quality Earth education opportunities: This claim covers reach into several specific high-leverage groups: pre-service K-12 teachers; students in humanities, social sciences, and non-geo STEM disciplines; minorities underrepresented in STEM; and students at institutions with no or limited geo faculty. In addition, Claim 2 documents InTeGrate's reach into the broader universe of faculty who adopt or adapt InTeGrate materials via InTeGrate's websites, publications and webinars, outside of targeted interventions or face-to-face PD events.

Claim 3: InTeGrate has contributed to the growth of a robust community of practice of geoscience educators and geoscience education researchers...: This claim is important because InTeGrate's leadership believe that it is the community of practice (CoP) that will carry InTeGrate's impact into the future, beyond the end of the current grant. CoP attributes attributed to InTeGrate in this claim are: repeatedly bringing together groups of people who share a concern and passion; mutual support in improving capacity for that practice; co-invention of new practices and new knowledge about the practice; and a feeling of being part of a community of shared interest. Claim 3 also asserts that at least some of the local and regional CoP's created or enhanced by InTeGrate are structured to endure, and that InTeGrate has advanced theoretical understanding of the dynamics of successful CoP's.

The strength of the evidence for the various subclaims varies. Some are backed up by multiple converging lines of empirical evidence, some are the considered professional judgment of the InTeGrate leadership based on their extended interactions with faculty and student participants, and some anticipate changes that will or may ripple forward into the future. Rather than set a very high evidentiary bar for which claims to include, this report tries to set forth the full of ecosystem of impacts and influences that InTeGrate purports to have affected. InTeGrate, and the higher education system within which InTeGrate

³⁸ Early versions of the suite of proto-claims included a fourth claim: "By working on national scale, and thinking systemically, InTeGrate has been able to achieve broader and deeper impact than can be achieved by smaller projects or single institutions." The critique of this claim was that it was unsupported based on only one project, with no comparison projects or institutions, so it was not included in this report. Some thoughts and evidence relevant to this claim were published in Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230.

functions, are complex systems. In studying complex Earth systems, geoscientists have found it beneficial to consider the whole system, rather than focusing only on those parts that are rigorously measurable; that approach has carried over into this report.

How to use this report

A few readers may read this report end to end. But the author anticipates that many others may wish to dip in here and there seeking insights about how InTeGrate tackled a particular problem or what InTeGrate learned about a particular question. For such readers, the report is structured in modular fashion, with the intent that individual sections could be read without reading all the preceding sections. As a consequence, the through-reader may find some redundancy; so be it. A comprehensive Table of Contents is provided to help insight-seekers, and detailed footnotes provide links to more information.

Accomplishing change in higher education on a nationwide scale, as InTeGrate aspired to do, requires attention to a bewildering assortment of different elements, players, influencers, components, processes and motivators. The time-honored organizational structure for directing a large-scale enterprise with big ambitions and many geographically-dispersed moving parts is a hierarchy, in which people higher in the organization tell people lower in the organization what to do, as in an army, big businesses, or the Catholic church. However, in higher education, on a nationwide scale, such an organization is unworkable: neither institutions nor individual faculty members in higher education are inclined to recognize the authority of other institutions or faculty members to tell them what to do. Instead, a different kind of organizational structure is required, with a stronger focus on collaboration, shared goals, co-developed procedures and processes, and governance by consent of the governed. InTeGrate provides a model for how this can be attempted, and a template for the many details that must be considered to make it work. These thoughts are gathered into Chapter 5 of this report, and two earlier publications.³⁹

Acronyms and Terms: Across 7+ years of intensive collaboration, colleagues deeply engaged in InTeGrate developed a shared vocabulary, which could be mystifying to newcomers. To help readers with these language hurdles, Exhibit I-5 provides definitions and links to further information about terms, phrases and acronyms used in writing about InTeGrate, both in this report and elsewhere.

A Note on Sources and References: The evaluation team had access to the full inward-facing InTeGrate web domain to access the internal deliberations and work pathways of the various teams. Inward-facing web pages, which are password protected, are indicated in the footnotes as “[Restricted access].” Some of the internal project website content could be made available to NSF, education researchers, or other qualified individuals on a case-by-case basis, to the extent consistent with InTeGrate’s IRB approval.⁴⁰

Acknowledgements:

This report represents the work of hundreds of people, in accordance with InTeGrate’s vision of a community-wide culture of evaluation in which everyone takes some responsibility for monitoring and

³⁹ Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230. Kastens, K. A., & Manduca, C. A. (2017). Leveraging the power of community of practice to improve teaching and learning about the Earth. *Change: The magazine of higher learning*, 49(5), pp. 14-22. See also Kezar, A., & Gehrke, S. (2015). Communities of Transformation and their Work Scaling STEM Reform: Pullias Center for Higher Education, Rossier School of Education, University of Southern California

⁴⁰ For further information, contact Ellen Iverson, SERC Internal Evaluator, eiverson@carleton.edu. Links to Excel files and other documentation that underlies many of the Exhibits in this report have been compiled at: https://serc.carleton.edu/integrate/workspace/kims_files_final_eval_report.html [Restricted access]

measuring progress towards agreed-upon goals. For design of the evaluation and associated instruments, as well as implementing various surveys, assessments, and interviews, thanks are due to evaluators C. Baldassari, D. Bragg, E. Iverson, and L. Wezstein, consultant F. Lawrenz, and the Assessment Team under the leadership of D. Steer and S. Birnbaum. Principal Investigator C. Manduca, the Leadership Team, the Advisory Board, and NSF Program Officers provided valuable insights into the evaluation effort. For the data herein, thanks are due to the classroom instructors who collected student data; the community members who filled out surveys and sat for interviews; the materials developers and IP team members who recorded their actions and reflections throughout the process; the Assessment Team members who scored open response student data; the SERC staff under the leadership of Sean Fox who built the technical infrastructure to capture, archive and analyze distributed data; and the SERC staff under the leadership of E. Iverson who gathered and analyzed the participant data, especially K. Sheriff. For the report itself, the author thanks A. Egger, S. Fox, J. Hehn, E. Iverson, L. Gilbert, P. Hutchings, C. Manduca, D. McConnell, and C. H. Orr for their reviews of all or part of the manuscript; Monica Bruckner for meticulous copy editing and fact-checking; and L. Gilbert and J. McDaris for permission to include data from unpublished manuscripts. InTeGrate was funded by the National Science Foundation's Directorate of Education and Human Resources and Directorate for Geosciences through grant DUE – 1125331.

Exhibit I-1: InTeGrate’s main program elements, each further explicated in the text. The arrows indicate synergism between activities, such that the outputs of one activity provide raw materials and inputs for other activities.

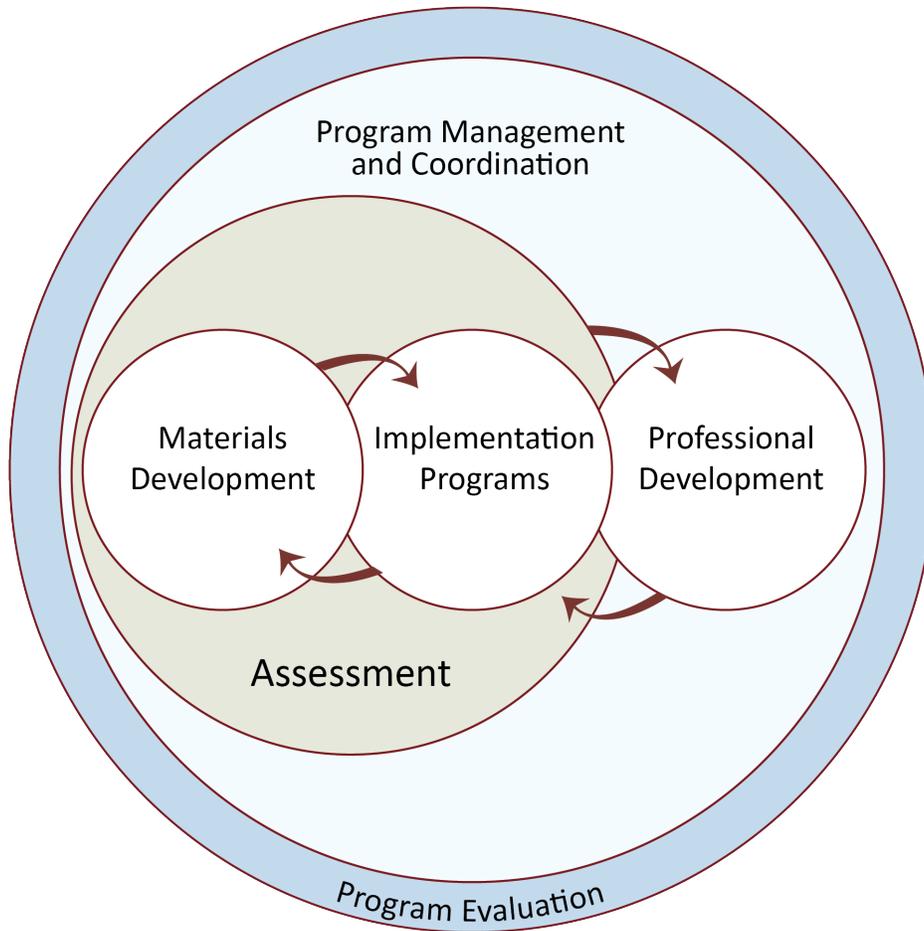


Exhibit I-2: Leadership team, their affiliations, and their responsibilities. Years, where shown, indicate project years that each individual worked on the project. If no years are shown, that person's involvement spanned Project years 1-8. To convert project years to calendar years, see Exhibit I-4.

Principle Investigator

Cathy Manduca <i>Carleton College</i>	Overall project management and coordination including interaction with advisory board and supporting organizations. Overall management of professional development program. Management of IP programs for first half of project. Coordination of Materials development effort across Co-PIs.
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Co-Principal Investigators

Tim Bralower <i>Penn State University</i>	Development and online publishing of interdisciplinary courses in support of certificate program, Penn State-UNO distance learning program, and implementation programs involving these materials.
Diane Doser <i>University of Texas–El Paso</i>	UTEP cluster implementation program involving El Paso Community College and dual-enrollment high school and implementation projects related to this model. Diversity & Inclusion.
Anne Egger <i>Central Washington Univ.</i>	Development and online publishing of materials supporting teacher preparation and interdisciplinary programs; teacher preparation IPs.
David McConnell <i>North Carolina State Univ.</i>	Development and online publishing of Intro modules. Co-lead of Research Team.

Additional Leadership Team Members

David Blockstein <i>NCSE</i>	Engagement of Environmental Studies/science programs through NCSE and CEDD; MD for interdisciplinary programs.
Felicia Davis (Yr 4-8) <i>Building Green Initiative</i>	Engagement of minority-serving institutions, faculty and students from groups underrepresented in STEM. Founder of HBCU working group.
Lisa Gilbert (Yrs 5-8) <i>Williams College--Mystic</i>	Research on student learning, and Assessment Team.
David Gosselin <i>Univ. of Nebraska-Lincoln</i>	Professional development activities related to sustainability; development teams and implementation programs resulting from this activity.
Richard Gragg III (Yr 6-8) <i>Florida A&M University</i>	HBCU working group leader. Leader of HBCU Research Team.
Sean Fox <i>SERC</i>	Website infrastructure development in support of publishing, assessment, and project management/leadership.
Ellen Iverson <i>SERC</i>	Assessment Team; Collection of assessment data; Internal evaluator.
Kim Kastens <i>Columbia & EDC</i>	Overall project evaluation.
Pamela Matson (Yr 1) <i>Stanford University</i>	Stanford implementation program.
Elizabeth Nagy-Shadman <i>Pasadena City College</i>	Engagement of faculty from two-year colleges, professional development activities aimed at this group, management of MD teams and IPs resulting from this work. Co-leader of Research Team.
Cailin Huyck Orr (Yr 3-8) <i>SERC</i>	Management of IP program and professional development activities aimed at IP teams.
Laura Serpa (Yr 1-2) <i>University of Texas–El Paso</i>	Engagement of minority-serving institutions, professional development activities aimed at this group.
David Steer, <i>Univ. of Akron</i>	Assessment Team Leader; development of Rubric and MD process.
John Taber <i>IRIS</i>	Management of Geoscience for Science Majors development teams, organization of Hazards workshop, engagement of IRIS community.

*Exhibit I-3: Names, expertise, and affiliations (during InTeGrate era) of members of InTeGrate's Advisory Board.*⁴¹

David Asai	Director of undergraduate education at the Howard Hughes Medical Institution, overseeing initiatives to reinvigorate life science education at research universities.
Sarah Bednarz	Associate Dean for Academic Affairs and Professor of Geography at Texas A&M University.
Teresa Bowers	President of Gradient, and environmental consulting firm.
Michael J. Carroll	Senior Staff Geologist at Hunt Oil Company, and president of the National Association of Black Geologists.
Geoff Feiss	GSA Foundation President, and Professor Emeritus at the College of William and Mary.
Grace Goldberg (student member)	Stanford University School of Earth Sciences.
Art Goldstein	Former Director of the Division of Earth Sciences at the National Science Foundation.
Jack Hehn	CEO of JH Consult, and former Director of Education, American Institute of Physics.
Pat Hutchings	Carnegie Foundation for the Advancement of Teaching; also National Institute for Learning Outcomes Assessment, and Gonzaga University.
Bob Krantz	Principal Structural Geologist at ConocoPhillips.
Stephanie Pfirman	Chair of the Department of Environmental Sciences, Barnard College.
Judith Ramaley	President Emerita, Winona State University. Formerly: Assistant Director of Education & Human Resources at NSF.
Joaquin Ruiz	Dean of the College of Science and Professor of Geochemistry, University of Arizona.
Jim Swartz	Associate Vice President and Professor of Chemistry, Grinnell College.
Lisa White	Director of Education and Outreach at UC Museum of Paleontology
Quinton Williams	Chair and Professor Physics, Howard University
Mary Lou Zoback	Consulting Professor, Stanford University; former Senior Research Scientist US Geological Survey Earthquake Hazards program

⁴¹ Additional information and links are at: https://serc.carleton.edu/integrate/about/advisory_board.html. Some individuals in this table served for less than the full duration of the InTeGrate grant.

Exhibit I-4: Chronology of events in the history of InTeGrate, organized by year and by program component. See Exhibit Acronyms for terms and abbreviations. Major landmarks are in bold face.⁴²

Project Year 1: December 2011 through November 2012	
Leadership, Administration & Infrastructure (Yr 1)	<ul style="list-style-type: none"> • December 1, 2011: NSF award began • PI presentation to NSF (Jan)
	<ul style="list-style-type: none"> • First face-to-face meeting of Leadership Team (Jan). Goal: to leave with a common vision and plan. Quarterly series of virtual leadership team meetings initiated.
	<ul style="list-style-type: none"> • First Advisory Board meeting (Oct). Recommendations include: extend logic model to institutional and international scale, develop non-geoscience-centric ways to discuss project.
	<ul style="list-style-type: none"> • First InTeGrate website launches, with general information about the project and information for materials development teams.
Diversity & Inclusion (Yr 1)	<ul style="list-style-type: none"> • Planning meeting on strategies for engaging two-year colleges and for increasing diversity in the geosciences (Feb). Recommendations include: 2YC member on each module team, materials with cultural and community relevance, form diversity advisory committee. • Compilation of broadening access literature begun
	<ul style="list-style-type: none"> • “Example course” (look and feel for a published module) developed • Organizational meeting for Teacher Prep materials development (Mar) • First open call for Materials Development Teams: Introductory Modules • Organization meeting for Intro. Geoscience Modules materials development teams (May) • Design rubric developed and made available to MD teams. • Open call for Materials Development Teams: Modules Outside of Geosciences (Aug) • Multiple presentations given at Geological Society of America, American Geophysical Union, and other national and regional meetings explaining program and inviting participation.
Implementation Programs (Yr 1)	<ul style="list-style-type: none"> • Various efforts to get Implementation Programs launched. Washington State IP plans for focus on Teacher Prep. El Paso area IP participates in Materials Development. James Madison IP drops out of program. Stanford and Penn State IPs struggle for footing. Efforts to catalyze additional IPs addressing diversity not successful.
Professional Development (Yr 1)	<ul style="list-style-type: none"> • First Professional Development workshop hosted by InTeGrate: Programs that Bring Together Geoscience & Sustainability (May 23-25).
	<ul style="list-style-type: none"> • A total of 4 workshops across the year addressing both teaching courses and program design and implementation
	<ul style="list-style-type: none"> • Materials Development process begins to emerge as PD for materials developers; likewise, membership on Assessment Team as PD for team members. • Workshop collections and syntheses from these activities published to support MD and IP.
Evaluation & Assessment (Yr 1)	<ul style="list-style-type: none"> • Nine-member Assessment Team established, drawing on over 90 applications (Mar). • Foundational decisions on student data types: list of consenting students; pre- and post-survey of attitude, demographics, motivation, career interest (IAI); pre-measure of Geo knowledge (GLE); embedded assessments specific to module/course; 2 post-instruction essay questions.
	<ul style="list-style-type: none"> • First f-t-f meeting of the Assessment Team, and first meetings between Assessment Consultants and MD Teams (May 2012). <i>Outcomes:</i> Revision of the InTeGrate Materials Design Rubric, first draft of Geoscience Literacy Exam (GLE), first version of IAI.
	<ul style="list-style-type: none"> • Workflow for materials testers designed, and technological infrastructure to support same implemented.

⁴² *Sources:* Project annual reports to NSF, Leadership Team email archive, PI quarterly updates to Leadership Team, notes in online workspaces from meetings of ITG Leadership Team and Advisory Board, Traveling Workshop Program Leadership Team meeting workspaces, Assessment Team email archive and online workspace, HBCU working group annual reports to project, email queries to SERC staff and Leadership Team members, and evaluator’s contemporaneous notes.

	<ul style="list-style-type: none"> • Evaluation instruments for faculty developers/tested designed: four sets of reflections, to be completed online.
	<ul style="list-style-type: none"> • InTeGrate participated in the design of the 3rd administration of the NAGT National Geoscience Faculty Survey, contributing new items relevant to ITG guiding principles.

Project Year 2: December 2012 through November 2013	
Leadership, Administration & Infrastructure (Yr 2)	<ul style="list-style-type: none"> • Leadership team meetings are grappling with big questions and ideas: envisioning desired state of ITG in 2017, thinking about scale of impact (larger than a single course), identifying kinds of materials not yet being developed, grappling with how to increase diversity in geoscience, how to market for adoption of materials. • Advisory Board (Oct): Where should remaining MD effort be focused? What is an IP? Recommendations include: strategies to have a bigger national impact, allow IPs to be creative and novel, start thinking now about Yr 6+ (what comes next). • Website revised to be less geoscience-specific, more user-friendly, and to showcase materials developed from Yr 1 workshops. • System developed to collect and track information about program participants, drawing information from various registration forms into a central database.
Diversity & Inclusion (Yr 2)	<ul style="list-style-type: none"> • Dr. Laura Sherpa, the original diversity lead, stepped down due to responsibilities in her home institution, and Dr. Tenea Nelson, of Stanford, took on this role. • Diversity plan developed. • Active recruitment of faculty from 2YC's and MSI's
Materials Development (Yr 2)	<ul style="list-style-type: none"> • All major elements of MD process in place and running smoothly: proposal review process, 3+ person interdisciplinary development team, guidance by Assessment Team member and MD Team Leader, backwards design, 28-item Materials Development rubric, consistent format for publishing, checkpoints with quality control at each checkpoint. • Usage of MD rubric stabilizes: document is finalized, passing thresholds established, inter-rater consistency is high. • First four MD teams completed development, passed rubric, pilot tested in classrooms and began revisions. Strategy of multiple developers from different institutions and pilot testing by developers found to yield insights about needed changes and additions. • Two open calls for new MD proposals yielded 19 proposals, from which 10 new teams were selected (4 intro, 2 teacher prep, 4 interdisciplinary). New teams, continuing teams, and assessment team held co-located working meetings, contributing to idea flow and peer support. • Preliminary version of publication template developed, along with plan for science review. • Web-based tools are in place to support MD and testing process: tracking interface for flow of data; internal tools for collecting and anonymizing student data, automatic scoring of multiple choice questions, and an interface for handling items that require manual scoring by the Assessment Team.
Implementation Programs (Yr 2)	<ul style="list-style-type: none"> • El Paso area IP team has begun work with materials that are under development. The rest of the IP program is on hold, waiting for a critical mass of instructional materials to become available and available leadership capacity.
Professional Development (Yr 2)	<ul style="list-style-type: none"> • PD program for developers ramped up, including May f-t-f meeting and 8 webinars. • Two ITG workshops focused on interdisciplinary interactions (engineering; environmental justice) and one partner workshop with Cutting Edge (oceanography) recruited new MD teams • Workshop on <i>Geoscience and the 21st Century Workforce</i>, followed by development of extensive website on same topic.⁴³

⁴³ <https://serc.carleton.edu/integrate/programs/workforceprep/index.html>

	<ul style="list-style-type: none"> • InTeGrate website reaches critical mass, with 700 pages, and 23,000 visitors. • Workshops are succeeding in attracting participants from outside geosciences, including business, chemistry, economics, engineering, English, history, math, natural resources, political science, philosophy, physics, and sociology.
Evaluation & Assessment (Yr 2)	<ul style="list-style-type: none"> • First analysis of student data from IAI survey and GLE (n=258), as well as embedded assessments and essay questions.
	<ul style="list-style-type: none"> • Review of assessment data from first pilot tests showed that embedded (formative) assessments are not adequate measures of module success; decision to switch to summative assessments.
	<ul style="list-style-type: none"> • First feedback to Materials Developers from Assessment Team and MD Team leaders (virtual and face-to-face at co-located May meeting).
	<ul style="list-style-type: none"> • Formative feedback from first round of materials developers (via reflections and focus groups): rubric is effectively nudging developers to identify goals and objectives and align student assessments with objectives, cross-institutional collaboration presents challenges, students find materials engaging especially those involving local environmental issues.
	<ul style="list-style-type: none"> • Interviews of selected project participants by external evaluator report that project leadership is committed and active; communication structures are functioning for planning and coordinating; team management processes are collaborative, inclusive and evolving. Challenges: short timeline, ambitious goals, leadership workload, inclusion of URM's.

Project Year 3: December 2013 through November 2014	
Leadership, Administration & Infrastructure (Yr 3)	<ul style="list-style-type: none"> • Leadership team continues quarterly meetings, 3 virtual, one f-t-f (July). Dealing with myriad of operational issues: what does the student data mean, what additional materials are needed, how to manage and evaluate IPs, what to do about diversity, how to broaden impact and build user base, need for more leadership capacity, planning for Rendezvous.
	<ul style="list-style-type: none"> • Advisory Board (Sept): “Vision of 2017”⁴⁴
	<ul style="list-style-type: none"> • First reverse site visit to NSF (Nov). Open presentation to NSF staff, and closed sessions with ITG program officers. Systems approach, community vision, synergy between materials>IPs>dissemination/adoption, pervasive culture of evaluation, technology for decision-support, approach to diversity, anticipated long term impact. NSF asked for evaluation results going forward to be cast in terms of claims and evidence.
	<ul style="list-style-type: none"> • Suite of tools, archives, databases and workspaces is now functioning in the inward-facing password-protected part of the InTeGrate website; mid-project evaluation report detailed how this technical infrastructure is being used to build community and support decision-making.
	<ul style="list-style-type: none"> • Website redesigned to be less geoscience-focused, more interdisciplinary, and to provide easy access to InTeGrate-developed materials.
	<ul style="list-style-type: none"> • Technical infrastructure migrated from Carleton College servers to Amazon Web Services, for greater speed, storage capacity, bandwidth and redundancy.
	<ul style="list-style-type: none"> • Management framework for IPs established (contracts, deliverables, timelines, etc.)
Diversity & Inclusion (Yr 3)	<ul style="list-style-type: none"> • Ongoing effort to recruit diverse individuals for all ITG activities has yielded 6 materials developers who work at MSI’s and 9 who work at 2YC’s, plus one Assessment Team member from an MSI.
	<ul style="list-style-type: none"> • First Spanish-language instructional material under development (adaption of Environmental Justice and Fresh Water Resources)
Materials Development (Yr 3)	<ul style="list-style-type: none"> • The first materials completed revision, science review, formatting for publication. By the end of project year 3, three modules had been published, 5 were in revision, and 6 had passed the rubric and were being piloted.
	<ul style="list-style-type: none"> • The portfolio was reviewed for coverage of audience, geoscience literacy principles, and critical societal issues. The final call for materials development teams (for start in Nov 2014) received 48 applications, of which 11 were selected, aiming to fill gaps in coverage.
	<ul style="list-style-type: none"> • By Oct 2014, 34 MD teams were at work or about to begin work. Two teams have dropped out of the program.
	<ul style="list-style-type: none"> • Following poor student performance on systems thinking essay: Systems thinking module commissioned, increased scrutiny of system thinking components during materials review, plan for webinar on systems thinking.
	<ul style="list-style-type: none"> • “Teacher Stash”: capacity for making selected web materials available only to vetted instructors
Implementation Programs (Yr 3)	<ul style="list-style-type: none"> • Two of the 3 IPs from original proposal (UTEP and Penn State) now teaching; Stanford IP has been redesigned.
	<ul style="list-style-type: none"> • First call issued for new IPs (March); 14 proposals received. Four teams selected for funding (Gustavus Adolphus; Wittenburg; Grand Valley State; Washington State).
	<ul style="list-style-type: none"> • Diversity workshop (Yr 1) and diversity plan (Yr 2) had not yield IPs focused on diversity/broadening participation. So two “diamond in the rough” teams with high potential for increasing diversity teams offered intensive coaching and invited to revise (Sept).
	<ul style="list-style-type: none"> • Second call for new IPs (October). By year’s end seven IP teams are in negotiation or in progress.
	<ul style="list-style-type: none"> • Web workspace and public web area established for IP teams.

⁴⁴ InTeGrate “Vision of 2017” draft document prepared for Advisory Board: https://serc.carleton.edu/admin/private_download.php?file_id=41648 [Restricted access].

Professional Development (Yr 3)	<ul style="list-style-type: none"> • Five face-to-face workshops. Workshops are serving PD purpose for participants, but are also gathering materials that are being worked into web-published content for MD teams, IP teams, and broader GeoEd community. • Mid-project evaluation report documents, based on written reflections and interviews, that the collaborative materials development process is serving as a strong PD activity for MD teams. MD teams comprise 119 faculty members from 64 colleges and universities. • Website now has >1000 pages of public content, reorganized into sections: “For Faculty and Instructors” and “For Program Directors and Administrators.” • New era of Traveling Workshop Program (TWP) begins, co-sponsored by NAGT, with new emphases on broadening participation, workforce preparation, and connecting to sustainability and environmental issues. TWP Leadership Training Workshop (July) solidifies decisions around new themes and sessions. • Decision is made to plan a single “megaworkshop” in future years (later called Earth Educators’ Rendezvous), as a more sustainable model than many small workshops. • To date, forty-nine individuals have been involved in workshop leadership, including people new to GeoEd leadership.
Evaluation & Assessment (Yr 3)	<ul style="list-style-type: none"> • For assessments specific to each module/course, the project switches from collecting formative assessments to collecting summative assessments for review by the Assessment Team, to better assess how well instruction is supporting the Guiding Principles. • The interdisciplinary problem solving essay question is yielding good data and informing materials developers. But the system thinking essay data are dubious, and two new candidate systems essay questions are developed and tested. • First version of faculty survey developed, the precursor to the IP faculty survey used later in the project. • Evaluation program was reviewed by consultant Frances Lawrenz, and plan for evaluation of IPs was developed with Lawrenz’s input. • Mid-Project Evaluation Report is submitted. <i>Highlights:</i> MD program is building collaborations and faculty capacity, as well as materials. IP program is getting off to a slower start than planned, but is going. PD program is reaching a broad audience with workshop and website, but project is not yet measuring impact on teaching or learning. Flows of information and influence have been mapped by graphic logic models. Project design draws on systems thinking. Technology is being used to build community and support decision making. • By end of year 3, student data has been collected from 1700 students in 41 courses. However, response rate has been lower than desirable, and project tries various approaches to incentivize both instructors and students.

Project Year 4: December 2014 through November 2015	
Leadership & Administration (Yr 4)	<ul style="list-style-type: none"> • Leadership Teams conduct quarterly virtual meetings and one face-to-face (May). Spinning up “research teams,” InTeGrate faculty survey, how to measure “reach,” how to scale up IP program, targeted calls to address gaps in materials portfolio, collaborating with other groups, understanding student data, supporting adoption/adaption. • Advisory Board (Sept): Recommendations include: Re: diversity: need a diversity chair on the leadership team, meet people where they are and support them from there; make sure faculty are rewarded for efforts; work on scale of department; attend to social media strategy. • Second reverse site visit to NSF (Oct). Team reports on: InTeGrate across space and time; Design principles for instructional materials; student and faculty outcomes; IPs. NSF replies: No more funding for STEP Centers. Re four proto-claims; NSF most interested in Claims 1 and 2, mildly interested in claim 3 (Community), and not interested in Claim 4 (Systems).
Infrastructure (Yr 4)	<ul style="list-style-type: none"> • Expanded project database now ingests information from multiple sources (IP reporting, materials developers tracking, individual users on website) and provides centralized tracking of classroom usage of materials and people engaged in ITG activities. • Technical support infrastructure developed for Earth Educators’ Rendezvous (online registration and fee-collection system, abstract collection and publication, workspaces for workshops, emails lists for interest groups) • Tools developed to support virtual communities (but uptake is minimal)
Diversity & Inclusion (Yr 4)	<ul style="list-style-type: none"> • Felicia Davis, director of Building Green initiative at HBCU Clark Atlantic University, joined Leadership Team • Workshop designed around concerns of MSI’s on Coastal Hazards, Risk & Environmental Justice (May 2015), with one goal of recruiting additional IPs from MSI’s. • By end of year 4, ITG people database includes 90 individuals from 2YC’s and 49 from MSI’s who have participated in workshops, MD teams, or other ITG activities. Of participants reporting race/ethnicity, 12% are from URM’s.
Materials Development (Yr 4)	<ul style="list-style-type: none"> • The last teams of Materials Developers were selected and began their work late in project year 4, with a target completion date of 30 November 2016, the original end date of the grant. • At the end of project year 4, 8 teams’ materials had been published, 10 were in final revision, 1 was being piloted, 15 were in development, and 1 had been terminated for lack of progress. • Dropped the goal of recruiting additional MD teams for upper division Geo courses.
Implementation Programs (Yr 4)	<ul style="list-style-type: none"> • Three new IPs began work in project year 4: Mercer Univ., California State Univ. at Chico, and the University of South Dakota. • Management and reporting framework developed for supporting IPs, with regular (quarterly and biennial) reports on products, participants, use of ITG curricular materials, successes, challenges, impact. • Public websites established for each IP, updated at least 2x per year, in a standard template. • External evaluator C. Baldassari begins a qualitative study of the impact of IPs on participating faculty and institutions. • Each IP is now required to develop and submit an evaluation plan before receiving funding, with help available from leadership team and assessment team, and then required to report results from evaluation 2x per year, for review by Assessment Team member. • Faculty survey for IP-involved faculty developed and piloted.
Professional Development (Yr 4)	<ul style="list-style-type: none"> • Seven f-to-f workshops. • First Earth Educators’ Rendezvous (July 2015, U of Colorado at Boulder), collaborative effort of NAGT and InTeGrate. >300 participants from many disciplines. • Webinar program launched (Feb 13, 2015). Nine webinars total, mostly intended for materials development teams, but open to all. • Traveling Workshop Program revitalized, with the addition of new themes on diversity, careers, and sustainability, and new leaders. Collaborative with On the Cutting Edge. TWP Leader Training Workshop (Jan): new sustainability-oriented leaders trained.

	<ul style="list-style-type: none"> • By end of year 4, ITG people database includes 717 individuals who have participated in workshops, MD teams, or other ITG activities, and 50 people have been leaders.
Evaluation & Assessment Yr 4)	<ul style="list-style-type: none"> • Assessment Team reviewed student data from new Systems Thinking essay, and concluded that the assessment is successfully measuring ITG guiding principle systems thinking.
	<ul style="list-style-type: none"> • Research Team initiated (June): 11 faculty will teach same Intro course without InTeGrate materials, then twice with ITG materials, while collecting common suite of student data.
	<ul style="list-style-type: none"> • Comparison of ITG student data versus control group of non-ITG students on interdisciplinary problem solving essay found ITG group likely to focus on topic of their ITG module.
	<ul style="list-style-type: none"> • First version of IP faculty survey administered (spring), following think-alouds with Gustavus and Wittenberg IPs.
	<ul style="list-style-type: none"> • Transition from using student data (summative assessments, GLE, essays) for developer feedback to new effort to use same data for project-level assessment: Assessment team developed rubrics, implemented sampling scheme, scored data from selected modules.
	<ul style="list-style-type: none"> • Faculty participating in MD program were observed with RTOP and were interviewed with TBI; instructional practices and beliefs moved towards student-centered.
	<ul style="list-style-type: none"> • A framework for thinking about the design, implementation, and evaluation of InTeGrate in terms of complex systems and systems maps was developed by external evaluator and project leadership, and submitted for publication.
	<ul style="list-style-type: none"> • Evaluation of Rendezvous participants by survey and interview showed strong development of new connections and gaining new teaching ideas were highly valued.
	<ul style="list-style-type: none"> • The first draft of InTeGrate “proto-claims” (basis for this report) were presented at the Advisory Board meeting (Sept) and refined through an interactive process.

Project Year 5: December 2015 through November 2016	
Leadership, Administration & Infrastructure (Yr 5)	<ul style="list-style-type: none"> • Advisory Board (Oct.): Explored IP products; discussed project impact. Recommendations include: focus on impact on faculty, devise a better way to estimate student numbers, evaluate community of practice impact, build out HBCU effort to other institutions.
	<ul style="list-style-type: none"> • Leadership Team (quarterly virtual meetings plus one f-t-f (May)): Emphasis shifts toward spreading impact: Evaluation claims, community building, engagement of MSI’s, marketing. How to be sustainable after end of grant; leaving a trace.
	<ul style="list-style-type: none"> • A system was developed to track classroom use or intended use of materials, with inputs from developers, IPs, teachers’ stash, pop-up surveys, and faculty survey, summing classroom use by # of students, # of instructors, institutions and institution type.
Diversity & Inclusion (Yr 5)	<ul style="list-style-type: none"> • HBCU Geoscience Working Group meets for first time at Earth Educators’ Rendezvous in Madison, WI. Agreed goals: culturally competent geoscience programs at HBCU’s and strengthening teacher preparation in Earth sciences.
	<ul style="list-style-type: none"> • El Paso IP is now reaching 500+ undergraduates per semester in El Paso area, with 12 instructors at 3 institutions with high Hispanic demographic.
	<ul style="list-style-type: none"> • Ten IPs have broadening participation as one of their stated goals or foci, including two HBCUs (Claflin Univ. and Savannah State Univ.) and three Hispanic-serving institutions (Cal State Chico, University of Illinois at Chicago, and the University of Texas at El Paso).
Materials Development (Yr 5)	<ul style="list-style-type: none"> • By the end of year 5, 16 modules had been published, 14 were in review, and 2 were in the final stages of review.
	<ul style="list-style-type: none"> • Materials for online and blended courses have been developed through the Penn State IP, totaling 70 weeks of instruction.
	<ul style="list-style-type: none"> • Materials have been adopted and adapted by IPs, Research Team, and participants in workshops and webinars, and have been presented at numerous conferences. Cumulative number of students exposed to ITG materials exceeds 30,000.
	<ul style="list-style-type: none"> • Introductory curriculum materials were analyzed for recurring design elements around teaching with data: five design patterns emerged.

	<ul style="list-style-type: none"> • Comparison of early and later MD cohorts shows that rubric scores at first review have improved over time, attributed to improvement in support system provided to MD teams.
Implementation Programs (Yr 5)	<ul style="list-style-type: none"> • Sixteen IPs active, across a range of institution types and goals, all aiming for a Nov 30, 2016 completion date. • Quarterly and biannual reporting system is yielding patchy input from the IP teams, making it hard to aggregate across the project firm numbers for students taught, faculty involved, materials used. Assessment team leads worked with IP leads to revise evaluation plans. • Publication format for IPs standardized, to support both dissemination of accomplishments and adoption/adaptation by others. • Faculty survey of IP faculty deployed. • Qualitative interview study of the impact of 6 early IPs on participating faculty and institutions. <i>Key finding:</i> IP must find an institutional fit with pre-existing goals of the broader institution so that change initiatives can be institutionalized. • Penn State IP has gained approval for Minor and Certificate programs in sustainability.
Professional Development (Yr 5)	<ul style="list-style-type: none"> • One f-t-f workshop, Rendezvous, 18 webinars. • Webinar format is now polished: a panel of presenters from multiple MD teams and IPs around a common theme, SERC staff facilitator, opportunities for reflection and discussion, posting of slides and video. • Nine of the IPs have presented their models in the webinar program. • Website has now reached 1600 pages of externally facing content; annual usage is up to 90,000 visitors. • Numerous presentations at regional and national conferences.
Evaluation & Assessment (Yr 5)	<ul style="list-style-type: none"> • Interviews of Rendezvous participants showed nearly all respondents reported a balance between contributing and receiving; surveys reported new teaching ideas, networking and community, and increased knowledge and understanding of diversity/cultural issues. • IAI results analyzed for ITG impact on students interested in K-12 teaching: the group most interested in teaching is more likely to report use of sustainability behaviors and to envision using knowledge of environment in their career. • IAI analysis toolkit developed to allow MD teams to analyze data for their own pilot students and compare them with a national survey. • GLE results available for 2,023 paired responses, showing 10% normalized gain, with students in lowest quartile pre-instruction showing the largest gain. • Methodology finalized for collaborative scoring of student essay questions, with sample from ITG and non-ITG courses. • RTOP classroom observations of faculty using ITG materials found to have average score of 52.5, contrasted with 39.7 for non-ITG classes (RTOP scales from 0-100, with 0-29 representing traditional lecture, 30-49 representing active lecture, and 5+ representing active learning). • Evaluation summit (May): leadership team and evaluators compiled lines of evidence (existing and desired) in support of anticipated end of project claims (“proto-claims”). • Research team completed data collection in Intro courses without ITG materials (Fall 2015), and with ITG (Spring and Fall 2016) • InTeGrate participated in the design of the 4th administration of the NAGT National Geoscience Faculty Survey, contributing new items around community of practice, systems.

Project Year 6: December 2016 through November 2017	
Leadership, Administration & Infrastructure (Yr 6)	<ul style="list-style-type: none"> • Leadership team (3 virtual meetings): Science reviews of materials; maximize use of TWP; website as a trading zone; NSF proposals for future work; Research Team progress; publications; IP models to webinar series. • NSF visit (Feb): Extending reach; HBCU working group; Lessons learned from IPs; Impact on student learning. • Advisory Board (Oct): Student impact; faculty impact; research directions; materials adoption; broadening impact (does the model replicate?). Discussion: what are the most strategic things to move forward? Teacher prep, diversity, research. • Website was redesigned to make it easier for visitors to find materials aligned with their interests. • New capacity added to search and browse instructional materials by NGSS element (disciplinary core ideas, science practices, cross-cutting concepts), by topic and grade level, by core teaching themes (e.g. systems thinking, spatial thinking), and by context (e.g. online).
Diversity & Inclusion ⁴⁵ (Yr 6)	<ul style="list-style-type: none"> • Two modules published with HBCU input.⁴⁶ • Three face-to-face-workshops co-convened by HBCU working group, held at HBCU's, and on topics of interest to HBCU community.⁴⁷ <i>Key outcome:</i> Ten Principles for Pan-African pedagogy for geosciences.” • HBCU working group began a research project testing impact of ITG materials on HBCU students and faculty. • First running of new Traveling Workshop theme: Supporting the Success of all Students. • By end of year 6, the data base of ITG participants included 1932 faculty, from 720 institutions across all 50 states, including 61 MSI's (11% of participants), 198 2YC's (20% of participants). Of participants who reported race/ethnicity, 9% identified as URM's.
Materials Development (Yr 6)	<ul style="list-style-type: none"> • By the end of year 6, 26 modules and 6 courses had been completed and published; one course was in final revision. • Most Materials Development teams have presented their project to broader audiences via InTeGrate webinars, Rendezvous posters/talks/demos, and/or by talks/posters at GSA/AGU. A few MD teams have written papers about their work. • A team of educators coded all InTeGrate materials for alignment with NGSS, and developed supporting materials to use ITG materials in NGSS-based instruction.
Implementation Programs (Yr 6)	<ul style="list-style-type: none"> • (Dec 2017) IP Synthesis meeting:⁴⁸ Face-to-face meeting of IP teams to pull together cross-IP lessons learned about attracting and supporting diverse learners, teaching Earth across the curriculum, supporting K-12 teaching, transitions, and making change happen. • First program models resulting from IPs are published. • Web area synthesizing lessons across all IPs has been published • Penn State IP hosted workshop on <i>Teaching about the Earth Online</i>, which expanded web guidance for faculty teaching online.

⁴⁵ Additional source: HBCU Geoscience Working Group 2017 annual report: https://serc.carleton.edu/admin/private_download.php?file_id=243260 [Restricted access]

⁴⁶ Food as the Foundation for Healthy Communities, and Lead in the Environment.

⁴⁷ Putting Sustainability into Action (Florida A&M, Oct 2017); Pan-African approaches to teaching Geoscience (Morehouse College, May 2017); Strengthening geoscience competency for HBCU pre-service teachers (Tennessee State University). Links from <https://serc.carleton.edu/integrate/workshops/index.html>

⁴⁸ Lessons learned from cross-IP synthesis were further developed by SERC staff after this meeting, and published here: <https://serc.carleton.edu/integrate/programs/implementation/index.html>

Professional Development & Dissemination (Yr 6)	<ul style="list-style-type: none"> • 6 workshops total, Earth Educators’ Rendezvous in Albuquerque, NM, 15 webinars. • (Jan) Traveling Workshop leadership met to prepare new themes on teaching about Earth in context of societal problems, supporting diverse learners into careers, and pre-service preparation of K-12 teachers. ~15 new leaders trained. Insights and content from InTeGrate IPs being woven into TWP. • Traveling workshops were offered at 8 institutions or regions. • (Mar) Research Team data analysis and synthesis meeting. • Website usage reached 130,000 visitors, with 70% of web traffic going to teaching materials. • Special issue of the Journal of Geoscience Education on sustainability education (May) had ITG leader as Associate Editor and three papers featuring ITG activities and products. • 43 presentations at professional society meetings.
Evaluation & Assessment (Yr 6)	<ul style="list-style-type: none"> • Analysis of IAI responses from ITG-using students and non-ITG using students showed more shift towards Earth interests and concerns among ITG students, with strongest effect among the students taking the course to satisfy a distribution or general education requirement. • New IAI toolkit used by MD teams and Research Team to analyze their own groups’ data and compare with a national sample. • Analysis of Systems Thinking essay questions shows that ITG students significantly outperform non-ITG students, and exceed the performance that would be predicted from their pre-instruction GLE score. • Analysis of GLE scores from students taught by the Research Team showed a significant gender gap in the control semester (female scores lower), and no gap in the treatment semester. • RTOP observations of the Research Team teaching with and without ITG materials showed a significant shift towards student-centered teaching practices in the treatment semester. • “Reach” surveys conducted to obtain lower bound on number of faculty using and number of students being taught with InTeGrate materials. • External evaluators Debra Bragg and Lia Witzstein of the University of Washington began interviews of a purposeful sample of faculty from three groups: highly-engaged creators, mentored (e.g. IP faculty), and un-mentored (e.g. workshop attendees). • NAGT National Geoscience Faculty Survey results analyzed by respondent’s level of engagement in ITG activities. Key finding: More ITG engagement correlates with higher commitment to, and perceived benefit from, geoscience education community. • Evaluation team and leadership developed a dynamic systems model for what drives GeoEd community of practice, and tested an aspect of this model (the “affective loop”) by lightning interviews at the Earth Educators’ Rendezvous in Albuquerque.

Project Years 7 & 8: December 2017 through November 2019	
Leadership, Administration & Infrastructure (Yr 7 & 8)	<ul style="list-style-type: none"> • Leadership team (2018: 3 virtual meetings): New data from NAGT faculty survey, student essays, faculty interviews, IAI. Impact on STEM or geo pipeline? Publications. What to sustain, and how: traveling workshops, webinars, Rendezvous, interest groups, website? How to keep modules current? • Post-grant web upkeep strategy developed, including mechanism to continue to track reach.
Diversity & Inclusion ⁴⁹ (Yr 7 & 8)	<ul style="list-style-type: none"> • Workshop on Diversity, Equity and Inclusion in the Earth & Environmental Sciences (April 2019, U of Illinois at Chicago) • Publication of three book chapters on InTeGrate's models for change in MSI's and 2YC's.⁵⁰ • Research project collects and analyzes student data from courses using InTeGrate materials at HBCU's.⁵¹ • HBCU geoscience working group established a formal relationship and permanent home with the National Technical Association (NTA), a professional society for minority professionals and students in STEM fields, and ran a workshop at the society's 2018 conference. • Comparison of student data from 2YC shows InTeGrate use closes 2YC-4YC achievement gap and increases interest in careers. • Sue Ebanks and collaborators, from the HBCU working group, were awarded an NSF GeoPaths grant for "GP-IMPACT: Expanding HBCU Pathways for Geoscience Education," with focus on teacher preparation and professional development. • 2019 Earth Educators Rendezvous co-hosted by an HBCU: Tennessee State University (with Vanderbilt University).
Materials Development (Yr 7 & 8)	<ul style="list-style-type: none"> • Final ITG course completes science and technical review, and is published! • Book chapters published on InTeGrate's MD process, rubric, and seven modules/courses.⁵² • New instructor stories from Research Team based on combining 12 or more units of ITG material into one course. • All instructor stories were categorized as to grade level, teaching context, and ITG materials used, and links in the stories based on these categories allow easy navigation to related materials.
Implementation Programs (Yr 7 & 8)	<ul style="list-style-type: none"> • Program models from all 16 IPs have now been published. • Book chapters published on InTeGrate's IP program, and on multiple specific IPs.⁵³

⁴⁹ HBCU Geosciences Working Group Annual Report 2018:

https://serc.carleton.edu/admin/private_download.php?file_id=249905 [Restricted access]

⁵⁰ Archer, R., Davis, F., Ebanks, S. C., & Gragg, R. D. S., III. (2019). HBCU's broadening participation in Geosciences (a journey through InTeGrate); Bellamy, A. S., Carrillo, G., & Nelson, T. W. (2019). Creating opportunities to teach and engage with undergraduates and faculty at two-year colleges and Minority Serving Institutions; and Doser, D., & Villalobos, J. (2019). Use of InTeGrate materials to engage instructors and encourage curriculum change in the El Paso Higher Education Community. All in D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Switzerland: Springer 386 pp.

⁵¹ HBCU Research Team website:

https://serc.carleton.edu/integrate/info_team_members/hbcu_testers_team/index.html

⁵² Barbanell, et al.; Brand, et al.; Boger, et al.; Cuker, et al.; Dere, et al.; Doner, et al.; Egger, et al.; Penny, et al.; Steer, et al. (2019). All in D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Switzerland: Springer, 386 pp.

⁵³ Orr & McDaris. Also, Doser & Hussein; Teasdale et al., Doser & Villalobos; Bellamy, et al; and Archer, et al. (2019). All in D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Switzerland: Springer, 386 pp.

Professional Development (Yr 7 & 8)	<ul style="list-style-type: none"> • Five workshops, Rendezvous in both 2018 (Lawrence, KS) and 2019 (Nashville, TN), 16 webinars in 2018, 4 webinars in 2019 (through April). • Third iteration of professional development for biological sciences faculty via QUBES Faculty Mentoring Network (FMN). • Travelling workshop program now has an NAGT program leadership committee and is being fully managed by NAGT, a structure sustainable post-InTeGrate. • Travelling workshop leaders meeting (Mar, 2018), on-boarded 8 new leaders, for a total of 48 leaders. • Ten travelling workshops in 2018; First implementation of two new ITG-inspired themes into TWP (Make your course more effective and societally relevant, Cross-campus environmental & sustainability programs). • Still trying to stimulate online interest groups; still little success.
Evaluation & Assessment (Yr 7&8)	<ul style="list-style-type: none"> • Book chapter published on development of InTeGrate’s suite of student assessments.⁵⁴ • Final IAI analysis across all available data, shows shift across instruction in student concern about and interest in the Earth and environment on every IAI item. • Further analysis of student products from paired ITG/ non-ITG samples shows that ITG outperform non-ITG on systems thinking even when students have equivalent Earth knowledge and essay-writing skills. • RTOP observations of Research team found that they incorporated more student-centered teaching practices into their teaching when adapting/adopting ITG materials. • Qualitative study⁵⁵ completed of a purposeful sample of faculty from three groups: highly-engaged creators, mentored (e.g. IP faculty), and unmentored (e.g. workshop attendees), addressing changes to pedagogy, community of practice, and emerging developments at scale larger than the individual faculty member. • Findings from faculty interviews on impacts after development (“downstream”): InTeGrate materials scaffold entry for faculty into deep discussions of interdisciplinary teaching; there is an interesting and perhaps synergistic relationship between active-learning/student-centered teaching and interdisciplinary approach.⁵⁶ • NAGT National Geoscience Faculty Survey results being analyzed to see if teaching in the context of societal issues, fostering geoscientific habits of mind, and/or the use of practices known to support diverse students have increased during the InTeGrate era. • “Reach” survey administered for the 3rd time to get a lower bound estimate on classroom usage of InTeGrate-influenced materials and ideas. Data coalesced into central database. • End of project evaluation report drafted, reviewed, revised, and completed.

⁵⁴ Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O’Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp. 91-119.

⁵⁵ Wetzstein, L., Kovacich, K., & Bragg, D. (2017). InTeGrate Faculty Study: Community College Research Initiatives: University of Washington.

⁵⁶ Iverson, E. R., & Wetzstein, L. (in press). Connecting learning about the earth to societal issues: Downstream effects on faculty teaching. In J. Ostrow (Ed.), *Teaching about Sustainability across Higher Education Coursework, New Directions for Teaching and Learning, No. 161*. San Francisco: Jossey-Bass.

Exhibit I-5: Terms, acronyms & abbreviations used in this report and other writings about InTeGrate. Each abbreviation and acronym is defined only once, under either the full name or the abbreviation, depending on which is more commonly used, and then cross-listed from the other location.

2YC	<ul style="list-style-type: none"> Two-year college. InTeGrate avoids the older terms “community college” and “junior college.” See also <i>SAGE 2YC</i>.
AESS	<ul style="list-style-type: none"> Association for Environmental Studies and Sciences. Organization advancing interdisciplinary environmental programs in education. “AESS book” refers to D. C. Gosselin, A. E. Egger & J. Taber (Eds.), (2019) <i>Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future</i>. Switzerland: Springer, 386pp.
AGU	<ul style="list-style-type: none"> American Geophysical Union. Term refers to both the organization and the annual conference, at which many MD and IP teams presented their work. AGU also hosted the Jan 2012 kickoff meeting of InTeGrate’s Leadership Team at their headquarters.
Assessment Team (AT)	<ul style="list-style-type: none"> Team of approximately a dozen faculty members, with expertise in both geosciences and student assessment, chosen by competitive application, and compensated with a stipend. The Assessment Team developed the <i>GLE</i>, the <i>Rubric</i>, and the two project-wide <i>essay questions</i>; served as “assessment consultants” for materials development teams; developed scoring systems for <i>embedded assessments</i> and <i>essay questions</i>; scored a subset of student products from pilot test classes, and provided feedback to Materials Development teams to guide the revision process.
AT	<ul style="list-style-type: none"> See <i>Assessment Team</i>
BSGD	<ul style="list-style-type: none"> See <i>Building Strong Geoscience Departments</i>
Building Strong Geoscience Departments (BSGD) ⁵⁷	<ul style="list-style-type: none"> An earlier geoscience education project, which shared some techniques, goals and personnel with InTeGrate; in particular, the <i>Traveling Workshops Program</i> grew out of the BSGD program.
CMS	<ul style="list-style-type: none"> Older name for the <i>SERC Content Management System</i>, now called the <i>Serckit</i>.
Cutting Edge	<ul style="list-style-type: none"> See <i>On the Cutting Edge</i>
DLESE	<ul style="list-style-type: none"> Digital Library for Earth System Education. An earlier NSF-supported project, which pulled together educators from across the geoscience domains, for collaborative work to build infrastructure in support of better teaching about the Earth. Part of the National Science Digital Library. The Earth Educators’ Rendezvous is a descendent of the DLESE summer conferences held annually throughout the early 2000’s.
EER	<ul style="list-style-type: none"> See <i>Earth Educators’ Rendezvous</i>
Earth Educators’ Rendezvous (EER)	<ul style="list-style-type: none"> Annual, week-long, summer gathering of educators and education researchers seeking to improve teaching and learning about the Earth, through a combination of workshops, posters, talks, round-table discussions, informal networking, and break-out meetings. Referred to as the “megaworkshop” in some early documents, the Rendezvous substituted for numerous single-focus workshops. Catalyzed by the InTeGrate project, the Rendezvous is now economically self-sustaining and run by <i>NAGT</i>.
“Embedded Assessments”	<ul style="list-style-type: none"> Assessments of student learning that probed student mastery of the learning objectives specific to a given module or course (as contrasted with the <i>GLE</i> and <i>IAI</i>, which were project-wide assessments). Student products from embedded assessments were collected by the project and a sampling of them were examined by the <i>Assessment Team</i> to gauge both effectiveness of the assessment and student learning towards InTeGrate’s <i>guiding principles</i>. In the early development rounds, the project collected formative assessments, student products generated in the course of an instructional unit. Later on, this requirement shifted to submission of a summative assessment, a student product from the end of the module or course.

⁵⁷ Website for BSGD project: <https://serc.carleton.edu/NAGTWorkshops/departments/about/index.html>

“essay questions”	<ul style="list-style-type: none"> • Usually refers to the two project-wide essay questions, that were administered post-instruction to students in pilot test classes, one question on interdisciplinary problem solving, one on systems thinking. Questions were developed and scored by the <i>Assessment Team</i>. • Occasionally refers to essay questions that were developed early in the project for each of the <i>geoscience literacy</i> big ideas; the earliest form of <i>GLE</i> had three questions per tested big idea, the most challenging of which was a short essay at high cognitive level.
GeoEd	<ul style="list-style-type: none"> • Shorthand for Geoscience Education. Spans education about the solid Earth, oceans, and atmosphere, including soils, hydrology, and cryosphere. • Sometimes includes Environmental [Science] Education, and sometimes is contrasted with Environmental [Science] Education.
Geoscience Literacies	<ul style="list-style-type: none"> • See <i>Literacies</i>
Geoscience Literacy Exam (GLE)	<ul style="list-style-type: none"> • See <i>GLE</i>
GeoPATHS	<ul style="list-style-type: none"> • NSF program for “Improving Undergraduate STEM Education: Pathways into Geoscience (IUSE: GEOPATHS). InTeGrate’s <i>HBCU</i> working group spearheaded a successful GeoPaths proposal.
GETSI	<ul style="list-style-type: none"> • Geodesy Tools for Societal Issues.⁵⁸ Another NSF-funded project that develops instructional materials using geoscience/geodetic data applied to societally important issues (climate change, natural hazards, water resources and environmental management). GETSI adapted InTeGrate’s <i>rubric</i> and <i>materials development</i> process, and some GETSI modules are cross-listed as InTeGrate modules.
GLE	<ul style="list-style-type: none"> • Geoscience Literacy Exam.⁵⁹ Variants: GLE-8, GLE-16, and full-GLE. Exam created by the <i>Assessment Team</i>, to test fundamental scientific knowledge/understanding about the Earth, as articulated in the consensus documents on Climate Literacy, Ocean Literacy, Earth Science Literacy, and Atmospheric Science Literacy. See also <i>Literacies</i>. Format includes questions at multiple cognitive levels and samples across all four literacies.
GSA	<ul style="list-style-type: none"> • Geological Society of America. Acronym can refer to either the organization or to the annual convention, at which many InTeGrate Materials Development and IP teams presented their work. GSA also hosted InTeGrate’s 2013 Leadership Team meeting at their headquarters in Boulder.
“Guiding principles”	<ul style="list-style-type: none"> • The first five elements of the InTeGrate materials development <i>rubric</i>, on which materials were required to obtain a perfect score. The elements are: Connect geoscience to grand challenges facing society; Develop students’ ability to address interdisciplinary problems; Improve student understanding of the nature and methods of geoscience and develop geoscientific habits of mind; Make use of authentic and credible geoscience data; Foster systems thinking.⁶⁰

⁵⁸ GETSI modules are linked from here: <https://serc.carleton.edu/getsi/index.html>, along with a description of the GETSI development process.

⁵⁹ The purpose, format, and development history of the GLE are summarized here: <https://serc.carleton.edu/integrate/about/gle.html>

⁶⁰ A full explication of the Guiding Principles is here: https://d32ogoqmya1dw8.cloudfront.net/files/integrate/info_team_members/currdev/documents/integrate_curriculum_development.v10.docx. The rationale behind them is developed here: Steer, D., Iverson, E., Egger, A., Kastens, K. A., Manduca, C. A., & McConnell, D. (2019). The InTeGrate materials development rubric: A framework and process for developing curricular materials that meet ambitious goals. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*, Switzerland: Springer, pp. 25-43.

HBCU, HBCU Working Group	<ul style="list-style-type: none"> Historically Black Colleges and Universities: A designation from the Higher Education Act of 1965 for colleges and universities “whose historical principal mission was, and is, the education of black Americans.”⁶¹ HBCU Geoscience Working Group: a group that advances teaching about the Earth at HBCU’s. This group formed as an InTeGrate team, and has now found a permanent home within the National Technical Association, a professional society for minority professionals and students in STEM fields.
HHMI	<ul style="list-style-type: none"> Howard Hughes Medical Institute. Funds efforts in program-level reform of STEM higher education, and provided some models for InTeGrate’s programmatic work. Hosted the 2017 InTeGrate Advisory Board meeting in Chevy Chase, MD.
IAI	<ul style="list-style-type: none"> InTeGrate Attitudinal Assessment: an online survey administered pre- and post instruction, asking for demographics, respondents’ reason(s) for taking the course, and probing respondents’ interest in college majors and career paths related to the Earth, plus their concern about environmental issues and motivation to contribute to solving environmental problems. Developed by the external evaluation team.⁶²
Implementation Program (IP)	<ul style="list-style-type: none"> Implementation Programs (IPs) were project-funded teams of educators who came together to take on a challenge in teaching about the Earth at a scale larger than a single course, within an institution or across a cluster of related institutions. Several IPs were included in the original NSF proposal, but most teams were selected through a competitive proposal system within InTeGrate. Each IP web-published information about what they did and what they learned; these products were called <i>IP program models</i>.⁶³
InTeGrate	<ul style="list-style-type: none"> Name of the project. Initially a quasi-acronym for “Interdisciplinary Teaching of Geoscience for a Sustainable Future.” Later changed to “Interdisciplinary Teaching about Earth for a Sustainable Future.”
InTeGrate Attitudinal Instrument (IAI)	<ul style="list-style-type: none"> See <i>IAI</i>.
IRB	<ul style="list-style-type: none"> Institutional Review Board on Human Subjects Research. Each institution that collected student data was required to have clearance from their institutional IRB. This was an unfamiliar process for many faculty, and thus an obstacle to project data collection; SERC staff needed to provide much support to faculty on IRB procedures.
IRIS	<ul style="list-style-type: none"> Incorporated Research Institutions for Seismology. A rich source of authentic geoscience data used in InTeGrate materials. InTeGrate’s 2014 Advisory Board meeting was hosted by IRIS at their Washington, DC headquarters.
IP	<ul style="list-style-type: none"> See <i>Implementation Program</i>.
ITG	<ul style="list-style-type: none"> Sometimes used as an abbreviation for InTeGrate.
“Literacies” or “Geoscience Literacies”	<ul style="list-style-type: none"> Summaries of the most important ideas and concepts in each of several branches of geosciences that need to be grasped by students, the public and policy makers, compiled through a nationwide collaborative effort, and summarized in “literacy documents.”⁶⁴ Literacy documents on Atmospheric Science, Climate, [solid] Earth Science, and Ocean Sciences pre-dated InTeGrate, were included in the InTeGrate <i>rubric</i> guiding principles, and tested by the <i>GLE</i>. A fifth literacy document, on Energy, came out during the InTeGrate project and was not formally incorporated into the <i>rubric</i> or <i>GLE</i>, but did inform some <i>Materials Development</i> teams.

⁶¹ Definition and listing of accredited HBCU’s is at: <https://sites.ed.gov/whhbcu/one-hundred-and-five-historically-black-colleges-and-universities/>

⁶² Purpose and development history of the IAI, plus links to the pre- and post-instruction forms of the survey instrument, are here: <https://serc.carleton.edu/integrate/about/iai.html>

⁶³ All 16 IP program models are linked from here, along with a synthesis of lessons learned across the IP program as a whole: <https://serc.carleton.edu/integrate/programs/implementation/index.html>

⁶⁴ A description of the geoscience literacy consensus-building process, plus links to each of the documents and supporting materials is here: https://nagt.org/nagt/teaching_resources/literacies.html

Materials Developers (MD)	<ul style="list-style-type: none"> • Also “Materials Development Teams” and sometimes “Materials Development Program.” Teams of 3 to 5 faculty members, from at least two different institutions, who collaborated to develop, pilot test, and revise teacher and learner materials for a specific InTeGrate course or module.⁶⁵ Team members received stipends linked to passing key development milestones. See also <i>Rubric</i>.
MD	<ul style="list-style-type: none"> • See <i>Materials Developers</i>. Same abbreviation sometimes used for Materials Development Teams or for the Materials Development Program.
MDRR	<ul style="list-style-type: none"> • Materials Development and Refinement Rubric. Usually just called “the Rubric” or “the InTeGrate Rubric.” See: <i>Rubric</i>.
“Megaworkshop”	<ul style="list-style-type: none"> • Early name for the annual, week-long convening now called the <i>Earth Educators’ Rendezvous</i>.
Module	<ul style="list-style-type: none"> • A cohesive body of instructional materials, comprising two to three weeks of instruction for the targeted audience. Most InTeGrate materials cover one module; a smaller subset cover an entire course. Each “module” comprises 3 to 6 “units,” and the intent is that other faculty members could adopt/adapt either the entire module or individual units.
MSI	<ul style="list-style-type: none"> • Minority-serving institutions. Institutions of higher education enrolling populations with significant percentages of undergraduate minority students.⁶⁶ See also <i>HBCU</i>.
NAGT	<ul style="list-style-type: none"> • See <i>National Association of Geoscience Teachers</i>.
National Association of Geoscience Teachers (NAGT)	<ul style="list-style-type: none"> • A professional association of educators and education researchers working to improve teaching and learning about the Earth. NAGT has taken over responsibility for several programs begun under InTeGrate, notably the Earth Educators’ Rendezvous and the Traveling Workshop Program.
National Council for Science & the Environment (NCSE)	<ul style="list-style-type: none"> • A Washington DC-based, non-partisan non-profit that does information dissemination, training, and curriculum development, as well as interdisciplinary research and scientific assessment.
NCSE	<ul style="list-style-type: none"> • See <i>National Council for Science & the Environment</i>.
Next Generation Science Standards (NGSS)	<ul style="list-style-type: none"> • See <i>NGSS</i>.
NGSS	<ul style="list-style-type: none"> • Next Generation Science Standards.⁶⁷ A set of standards for K-12 science teaching, which emphasizes how science is done alongside what science has discovered. NGSS was published early in the InTeGrate era and strongly guided the teacher-preparation component of InTeGrate. NGSS and InTeGrate overlap in important ways, including the focus on Earth/human interactions, analysis and interpretation of authentic data, and collaborative interdisciplinary problem solving.
NSF	<ul style="list-style-type: none"> • National Science Foundation, funder of InTeGrate. Funding was shared between two Directorates: Geoscience (NSF/GEO) and Education & Human Resources (NSF/EHR)
On the Cutting Edge	<ul style="list-style-type: none"> • An earlier geoscience education project, which shared some techniques, goals and personnel with InTeGrate, especially the synergistic combination of workshop and website. Some early InTeGrate workshops were co-sponsored with Cutting Edge; these were referred to as “partnership workshops.”
“partnership workshop”	<ul style="list-style-type: none"> • See <i>On the Cutting Edge</i>.

⁶⁵ A roadmap to guide Materials Development Teams through the entire process from forming their team to publishing their materials is here: https://serc.carleton.edu/integrate/info_team_members/currdev/index.html

⁶⁶ A listing of such institutions is maintained by the U.S. Department of Education at: <https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html>

⁶⁷ The portal to InTeGrate’s body of supporting materials for instructors who want to teach about the Earth in an NGSS-compatible way is here: https://serc.carleton.edu/integrate/teaching_materials/ngss/index.html

PD	<ul style="list-style-type: none"> Professional Development. In InTeGrate’s case, programming and interactions that improve faculty’s capacity to do their job well. One of the three major components of InTeGrate articulated in the original proposal. Accomplished through programming that has PD as its overt goal (e.g. workshops and webinars) and also through other interactions such as collaborative co-development of instructional materials.
“Reach,” “reach survey”	<ul style="list-style-type: none"> “Reach” was used to refer to how many students and faculty were being influenced or impacted by InTeGrate’s materials and ideas. Various surveys were implemented to quantify reach, especially among faculty who were part of subaward activities (such as workshop/webinar attendees) and people downloading materials from the website. All reach statistics are viewed as lower-bound estimates.
Reformed Teaching Observation Protocol (RTOP)	<ul style="list-style-type: none"> See <i>RTOP</i>.
Rendezvous	<ul style="list-style-type: none"> See <i>Earth Educators’ Rendezvous</i>.
RTOP	<ul style="list-style-type: none"> Reformed Teaching Observation Protocol. A methodical system in which a trained observer watches classroom instruction in a college-level science or math class and documents the extent to which classroom instruction uses student-centered, engaged learning practices. RTOP has been used since 2011 in geoscience classrooms nationwide, including many where ITG materials are in use.
“Rubric” ⁶⁸	<ul style="list-style-type: none"> Also “InTeGrate Rubric,” “Materials Development Rubric,” “Materials Design Rubric,” and “Materials Development and Refinement Rubric (MDRR).” A set of principles for the design and refinement of instructional materials, developed and enforced by the <i>Assessment Team</i>, and implemented by the <i>Materials Developers</i>. See also <i>Guiding Principles</i>.
SAGE 2YC ⁶⁹	<ul style="list-style-type: none"> Another NSF-funded geoscience education program: Supporting & Advancing Geoscience Education at Two-year Colleges. SAGE 2YC shared some personnel and goals with InTeGrate.
SERC	<ul style="list-style-type: none"> The Science Education Resource Center, at Carleton College. Headquarters for InTeGrate; source of management, evaluative, and technical support; and host of InTeGrate’s technical infrastructure.
Serckit	<ul style="list-style-type: none"> Web platform designed and supported by SERC, optimized to support collaboration around teaching and learning, and sharing and finding of resources and ideas. Previously called the CMS or Content Management System. See: https://serc.carleton.edu/serc/about/serckit.html
STEM	<ul style="list-style-type: none"> Science, Technology, Engineering & Mathematics. Usually refers to educational efforts or careers that intertwine several of these disciplines (also called integrated STEM), but may also refer to the disciplines individually.
STEP	<ul style="list-style-type: none"> STEM Talent Expansion Program. An NSF program, which included large STEP Centers,⁷⁰ such as InTeGrate.
TBI	<ul style="list-style-type: none"> See Teaching Beliefs Interview
Teaching Beliefs Interview (TBI)	<ul style="list-style-type: none"> Semi-structured interview consisting of seven questions that probe instructors’ pedagogical beliefs. Administered pre- and post- ITG involvement to a subset of <i>Materials Developers</i>.

⁶⁸ A webinar explaining the rubric is archived here:

<https://serc.carleton.edu/integrate/workshops/webinars/2015/rubric.html>. Information provided for Materials Developers is here: https://serc.carleton.edu/integrate/info_team_members/currdev/rubric.html

⁶⁹ Original SAGE 2YC program, beginning in 2011: https://serc.carleton.edu/sage2yc/about/prior_work.html. Successor program, beginning in 2015: <https://serc.carleton.edu/sage2yc/about/index.html>

⁷⁰ Program solicitation for Science, Technology, Engineering and Mathematics Talent Expansion Program Centers (STEP Centers): <https://www.nsf.gov/pubs/2010/nsf10569/nsf10569.htm>

Traveling Workshops Program (TWP)	<ul style="list-style-type: none"> • An initiative begun by the <i>Building Strong Departments</i> program, and continued through InTeGrate, and now under the auspices of <i>NAGT</i>. This program brings a leader skilled in geoscience and pedagogy to a campus or to a central locality accessible to several related campuses.
TWP	<ul style="list-style-type: none"> • See <i>Traveling Workshops Program</i>
Under-represented Minority (URM)	<ul style="list-style-type: none"> • See <i>URM</i>.
Unit	<ul style="list-style-type: none"> • See explanation under <i>Module</i>.
URM	<ul style="list-style-type: none"> • Under-represented Minority. Term is used as a noun referring to an individual and as an adjective referring to a group. Usually refers to groups underrepresented in STEM, and for NSF purposes that includes individuals who report themselves to be partly or entirely Hispanic/Latinx, Alaskan Native, American Indian/ Native American, Black/African American, or Pacific Islander. Note that Asians and Asian-Americans are not classified by NSF as URM's in STEM.

Chapter 2

Claim #1: Teaching about the Earth has improved in pedagogy and relevance under the influence of InTeGrate

Claim 1 says that InTeGrate has developed new and better ways to teach about the Earth, and to assess those teachings. “New and better” in this context involves (a) use of evidence-based, student-centered pedagogy, and (b) connecting course material with real world issues and problems. Within InTeGrate, these two forms of improvement are tightly intertwined and synergistic. High-stakes, authentic problems such as natural hazards, climate change, and water scarcity, form the context for students to engage in deep learning through use of authentic data, realistic decision-making scenarios, role playing, community service, and other student-centered learning opportunities.¹

Claim 1 encompasses the following sub-claims:

- ***Sub-claim 1A: InTeGrate has created and refined a system/process for collaborative development and testing of instructional materials, with potential to improve future curriculum development efforts.***
- ***Sub-claim 1B: InTeGrate teams have developed, tested, and disseminated pedagogically excellent instructional materials that embed teaching and learning about the Earth in the context of societally-important problems.***
- ***Sub-claim 1C: Faculty who engage with InTeGrate's materials and associated professional development shift in beliefs and practice towards research-tested pedagogies and teaching about the Earth in the context of societal/environmental issues.***
- ***Sub-claim 1D: InTeGrate has developed infrastructure for collaborative, distributed assessment of student learning, as well as instruments to measure students' geoscience literacy, attitudes towards Earth-related issues and careers, and their ability and motivation to contribute to solving environmental grand challenges.***
- ***Sub-claim 1E: Students who are taught with InTeGrate materials increase in their geoscience literacy, their interest in Earth-related majors and careers, and their ability and motivation to contribute to solving challenges of environmental sustainability and resource limitations.***

Exhibit II-1 sketches a simplified version of InTeGrate’s model of how these sub-claims fit together into a system with the potential to improve teaching and learning. The flow of influence begins with a system of collaborative development of instructional materials by multi-institutional teams, guided by the rubric and supported by the Assessment Team (sub-claim 1A). This leads to a substantial body of high-quality instructional materials (sub-claim 1B). With good materials to teach from, faculty improve their teaching practice (sub-claim 1C), especially if they have access to InTeGrate professional development as

¹ Based on interviews with InTeGrate faculty, Iverson & Wetzstein (in press), raise the possibility that there is a constructive interaction between active learning techniques and sustainability curricula. Faculty interviewees suggested that campus sustainability initiatives can be an on-ramp for active-learning techniques, and conversely that faculty who already have expertise in employing such techniques may find adopting effective sustainability curricula to be an easier learning curve. Iverson, E. R., & Wetzstein, L. (in press). Connecting learning about the earth to societal issues: Downstream effects on faculty teaching. In J. Ostrow (Ed.), *Teaching about Sustainability across Higher Education Coursework, New Directions for Teaching and Learning, No. 161*. San Francisco: Jossey-Bass. If this is true, then InTeGrate’s juxtaposition of these two changes could have resulted in total improvements more than the sum of the parts.

well as materials. Better teaching practice, in turn, results in improved student learning (sub-claim 1E.) Student learning must be inferred from student performance on concrete assessments, so sub-claim 1D speaks to the development of instruments and a technical and organizational infrastructure to probe student learning across the nation-wide project.

All of these sub-claims speak to changes that have the potential to be long-term rather than temporary. Sub-claim 1A and the first part of sub-claim 1D speak of the development and refinement of new systems by which a distributed network of faculty members can collaborate to accomplish challenging educational goals more effectively than they could have done as individuals: a system for developing and testing instructional materials (1A), and a system for gathering and scoring assessment data from a broad national sample of courses and institutions (1D). These systems are suitable for re-use in other projects, and such re-use is beginning. These sub-claims are tightly coupled to the community of practice described in Claim 3, in that the existing community enabled the rapid spin-up of these distributed collaborative efforts and the collaborative process, in turn, wove new and stronger threads through the community.

Claims 1B and the second part of 1D speak to new materials (1B) and instruments (1D) that have been developed and will continue to be made freely available after the current grant sunsets. InTeGrate's materials are the most immediately conspicuous of the traces that the project is leaving. As InTeGrate has reached out to new audiences (as described in Claim 2) the instructional materials have often been the lure that attracts new faculty into the InTeGrate sphere of influence.

Claims 1C and 1E speak of people who have been changed: instructors who have changed their beliefs and teaching practice (1C) and students who have changed their motivation and ability to tackle environmental grand challenges (1E). It is in these two sub-claims that the rubber really hits the road: these changed students have the potential to go forth and help humanity better understand how our planet works and use that understanding to solve problems at the Earth-human interface. These changed instructors have the potential to keep bringing forth new students with this set of motivations and abilities.

The level of evidence associated with the sub-claims varies. But collectively, the components of Claim 1 assert that places and people touched by InTeGrate have experienced better teaching and learning about the Earth than would have happened in the absence of InTeGrate.

* * * * *

Sub-Claim 1A: InTeGrate has created and refined a system/process for collaborative development and testing of instructional materials, with potential to improve future curriculum development efforts

Although the pre-InTeGrate Geoscience Education community had a well-developed culture of sharing and reuse of instructional resources, there was little to no prior experience in collaborative development or testing of instructional materials. Both the human structures and technological underpinnings had to be created from scratch. Known problems that needed to be addressed included: faculty may lack time or resources to engage in rigorous curriculum development, may lack the expertise and setting in which to test the effectiveness of the materials, may have trouble identifying colleagues to work with on an interdisciplinary team, may lack experience working on an interdisciplinary team, and/or may not know how to customize materials to their institutional and regional setting.²

² Egger, A., Bruckner, M. Z., Birnbaum, S. J., & Gilbert, L. A. (2019). Facilitating the development of effective interdisciplinary curricular materials. In Gosselin, D.C., Egger, A.E., Taber, J.J., (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 45-68, and references therein.

Creation and refinement of the materials development system

The components of InTeGrate's curriculum development system³ include:

- *teams of 3-7 faculty members* from multiple institutions, with differing expertise, typically including multiple geoscience disciplines and often including members with other science specializations or non-scientists (e.g. economists);
- *a recruitment and selection process* for engaging, matching-up, and selecting development teams, through workshops,⁴ notices on listservers, etc.
- *the InTeGrate curriculum development and refinement rubric* (Exhibit II-2),⁵ which was used to communicate InTeGrate's expectations to materials developers and Assessment Team, to gage materials' progress towards the ready-to-pilot stage, and to refine the professional development program for materials developers;
- *collaboration tools for materials developers*, including email lists and password-protected web areas for sharing segments of materials in progress and supporting documents;
- *the Assessment Team*, who guided the Materials Development Teams, reviewed materials at several steps during the development process, and developed and scored student assessments;
- *an Assessment Consultant* who worked with members of the Materials Development Team to ensure their materials matched the InTeGrate rubric;
- *collaboration tools* for the Assessment Team, to facilitate the review of materials against the Development Rubric, view and score anonymized student assessments, and provide password-protected web spaces to communicate with one another and store notes;
- *a defined sequence of checkpoints*, spanning from initial ideas to published module or course;
- *face-to-face meetings* involving materials developers, the Assessment team, members of the project Leadership Team, and support staff;
- *web consultants*, from SERC's staff, who provided technical assistance throughout the development process, tracked and nudged the team's progress through the checkpoints especially the pilot testing and review processes, assisted with data collection, and coached the development teams on preparing their materials for web publication;
- *content area leaders*, from InTeGrate's Leadership Team, who functioned similarly to a journal editor;

³ Egger et al. (2019), *op cit.* Also: InTeGrate Teaching Materials Development:

https://serc.carleton.edu/integrate/teaching_materials/itg_materials_dev.html

Information for Materials Developers: https://serc.carleton.edu/integrate/info_team_members/currdev/index.html

⁴ The way in which in-gathering workshops were used to engage and assemble teams, ideas and materials for the materials development program was discussed in the mid-project evaluation report and featured in Kastens & Manduca (2017) as an exemplar of how major elements of the InTeGrate system were designed to support and feed into each other. For example, two materials development efforts arose out of the 2013 workshop on "Teaching Environmental Justice: Interdisciplinary Approaches." These were Environmental Justice and Freshwater Resources and Mapping with Sensory Perception. Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230.

⁵ An elaboration of each rubric element is provided at:

https://d320goqmya1dw8.cloudfront.net/files/integrate/info_team_members/currdev/documents/integrate_curriculum_developme.v10.docx

- *the SERCkit*, a content management system optimized for use in education, plus faculty capable of using the SERCkit, and SERC staff ready to coach and advise on such use;
- *a publication template*,⁶ such that all modules and courses followed the same format when published on the web (modules are 2-3 weeks of material; courses are meant to cover an entire semester or quarter);
- the “*teacher stash*,” a mechanism for keeping answer keys and similar materials confidential;
- *a technical review process*, ensuring that materials align with the required format and include all required components, and that copyright procedures have been followed;
- *science content reviewers*, mostly drawn from outside the InTeGrate project, who provided reviews of the materials just prior to publication;
- *a publication venue*, for the completed materials;
- *supporting web pages* that curriculum materials can link to, including as pages on recommended pedagogical practices and key InTeGrate themes; and
- *a search and browse system* to allow potential users to find ITG-created materials aligned with their needs and interests.

The evolution of the materials development process can be described as a rapid spin up of a complicated system with intertwined human and technological components, followed by continuous improvement in response to observations of strengths and weaknesses. Thirty-two interdisciplinary teams of 110 unique authors from around the country and from many institution types completed the process, producing 26 modules and 6 courses (Exhibit II-3). Every team had at least one geoscientist on the development team, 15 teams had a non-geo scientist, and 10 teams included a member who was not a natural/physical scientist (such as an economist or sociologist). Three teams did not complete the process, and terminated their contracts early in the process by mutual agreement with the leadership.⁷

As an example of how the materials development process evolved in response to early observations, Steer and colleagues (2019)⁸ have documented how the rubric was used to refine the materials development process over time. The initial and intended uses of the rubric were to convey InTeGrate’s expectations and priorities to the materials developers and to gage the progress of the materials towards the ready-to-pilot stage. When the Assessment Team reviews of the first cohort of materials came in, at the step where materials were being considered for pilot testing, it became clear that certain of the rubric elements were presenting substantial hurdles for the materials developers (Exhibit II-4). Weakest average scores were on rubric elements 1.5 (systems thinking), element 2.2/3.2 (developing criterion-referenced grading rubrics), element 4.2 (linking materials to learning outcomes), and element 5.3 (fostering student metacognition).

⁶ All ITG materials have a cover page, overview with a table of contents, unit pages, a page that lists out the assessments, a stand-alone ‘student materials’ section that can be shared directly with students, a set of instructor stories documenting their pilot implementations, and a community discussion thread. Teaching Materials Format: https://serc.carleton.edu/integrate/info_team_members/currdev/teacher_format.html [Restricted access]

⁷ Egger et al. (2019), op. cit.

⁸ Steer, D., Iverson, E., Egger, A., Kastens, K. A., Manduca, C. A., & McConnell, D. (2019). The InTeGrate materials development rubric: A framework and process for developing curricular materials that meet ambitious goals in Gosselin, D.C., Egger, A.E., Taber, J.J., (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer. pp. 25-44.

The project leadership and Assessment Team responded to these observations by adding more scaffolding for materials developers.⁹ Web pages were developed on such topics as developing effective learning goals and metacognition.¹⁰ A series of professional development webinars and supporting web pages were offered to support the materials developers¹¹, covering use of the InTeGrate Materials Development rubric, developing systems thinking, backwards design, designing and using rubrics in assessments, metacognition, and designing and aligning learning outcomes and assessments. The materials developers' face-to-face meetings were reorganized to explicitly cover key rubric elements, and time was built in to the program for team leads and assessment consultants to review and offer formative feedback on team's initial ideas on how to incorporate these elements into the emerging module. Following these changes, Cohorts 2 and 3 generally achieved higher average scores on the rubric elements than had cohort 1 (Exhibit II-4) when their materials were presented for audit prior to pilot testing.

The materials development program was part of InTeGrate's effort to establish an evaluation culture throughout the Geo-Ed community [see Introduction.] Five of the 28 rubric elements were about assessment, requiring that assessments: measure the stated learning outcomes, are criterion-referenced, are consistent with course activities, progress from lower to higher cognitive levels, and are "sequenced, varied, and appropriate to the content." In practice, the last two elements meant that both formative and summative assessments were required. The intent was that repeated work on these elements with other team members and with the Assessment Team consultant would inculcate these priorities into the professional practice of the materials developers in a lifelong fashion. The Assessment Team members were chosen as geoscience educators who already had expertise in assessment, but the intent was that they too would deepen their ability to assess student learning outcomes and evaluate curriculum materials.

Adaptation of InTeGrate system to improve non-InTeGrate curriculum development efforts

One other mature curriculum development effort has adopted major components of the InTeGrate curriculum development process. GETSI¹² is an NSF-funded project under the direction of UNAVCO (a consortium of universities that do research related to deformation of the solid Earth). They adopted the following components of the InTeGrate process: a focus on teaching in the context of societal issues, multiple-institution developer teams, face-to-face materials developers' workshops,¹³ a rubric to guide developers with most of the same elements as the InTeGrate rubric, a development timeline and checkpoints, pilot enactments with pre/post assessment, post-piloting revision, and publication format.¹⁴ They modified the rubric to replace systems thinking with quantitative reasoning,¹⁵ and used a round-

⁹ *Ibid.*

¹⁰ Egger, A., Bruckner, M. Z., Birnbaum, S. J., & Gilbert, L. A. (2019). Facilitating the development of effective interdisciplinary curricular materials. In Gosselin, D.C., Egger, A.E., Taber, J.J., (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 45-68.

¹¹ Webinars: <https://serc.carleton.edu/integrate/workshops/webinars/2015/index.html>,
https://serc.carleton.edu/integrate/workshops/webinars/2015_2016/index.html and
<https://serc.carleton.edu/integrate/workshops/webinars/past/index.html>
Supporting web pages:

https://serc.carleton.edu/integrate/info_team_members/currdev/effective_materials/index.html

¹² Geodesy Tools for Societal Issues: <https://serc.carleton.edu/getsi/index.html>

¹³ GETSI Team Meetings: <https://serc.carleton.edu/getsi/meetings/index.html>: 4 multi-day face-to-face workshops and 11 webinars.

¹⁴ GETSI Module Development Timeline: https://serc.carleton.edu/getsi/info_team_members/timeline.html Includes timeline, plus details of what happens at each step from signing contract through publication.

¹⁵ GETSI Material Developers' Rubric, downloaded from:
https://d320goqmya1dw8.cloudfront.net/files/getsi/info_team_members/getsi_materials_development_ru_1392755300.v3.docx

robin review process in place of a dedicated Assessment Team. The GETSI modules are sufficiently similar to the InTeGrate modules in both presentation and goals that they are now being published on the InTeGrate materials page, with a small flag noting that they are “From GETSI.” As of 27 Sept 2018, there were seven GETSI modules completed and six more in development.¹⁶ Five of the GETSI modules are for majors, which helps to balance out the offerings as the majority of the InTeGrate-developed modules are at the Intro level.

As noted above, GETSI adopted and adapted the InTeGrate Materials Development Rubric, which embeds many of InTeGrate’s most cherished priorities and values in the form of an artifact. But in addition to the written document, InTeGrate’s methods and ideas were also passed from InTeGrate to GETSI in the form of individuals who transitioned from one project to the next, carrying their experience with them.¹⁷ Ellen Iverson of SERC served as evaluator and assessment consultant. Three individuals (Exhibit II-5) who had been InTeGrate developers later emerged as GETSI developers. Because of multiple authorships, 5 of the 12 GETSI modules, either published or in development, had an author with prior InTeGrate authoring experience.

In addition to the mature GETSI effort, several NSF education proposals have included use of aspects of the InTeGrate development process. So far, one has been funded. The Environment Data-driven Inquiry and Exploration (EDDIE): Using Large Datasets to Build Quantitative Reasoning project¹⁸ seeks to develop modules that enable undergraduates to explore real world data from biology, geology and the environmental sciences. An explicit goal of EDDIE is to develop a community of instructors who support each other across the transition from traditional to inquiry-based pedagogy, improve teaching of quantitative reasoning skills, and potentially transform how data science is taught. InTeGrate veteran, Cailin Huyck Orr, is a co-PI.

* * * * *

Sub-Claim 1B: InTeGrate teams have developed, tested, and disseminated a substantial body of pedagogically-excellent instructional materials that embed teaching and learning about the Earth in the context of societally important problems.

This claim rests on evidence about the quantity of materials produced, quality of individual modules/courses, scope of the portfolio of materials, versatility of the materials for use in different contexts, incorporation of elements that are educative for faculty, and uptake of the materials by faculty who were not involved in developing them.

Quantity

Twenty-six modules and 6 courses have been developed, and tested, and published.¹⁹ The last of the courses (The Future of Food) was published in January 2018, to much rejoicing. Exhibit II-3 summarizes the modules and courses along with some of their attributes. In addition, 6 modules were developed by the GETSI project using a variant of the InTeGrate curriculum development process, and are published in the same location in the same format as the purely InTeGrate modules.

¹⁶ GETSI Teaching Materials: <https://serc.carleton.edu/getsi/index.html>

¹⁷ This process of transferring insights and experience from activity to activity by the migration of human beings was described by Kastens & Manduca (2017).

¹⁸ Award Abstract #1821567: Collaborative Research: Environmental Data-Driven Inquiry and Exploration (EDDIE): Using Large Datasets to Build Quantitative Reasoning: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1821567&HistoricalAwards=false

¹⁹ InTeGrate teaching materials are linked from: https://serc.carleton.edu/integrate/teaching_materials/index.html

The project timeline in the InTeGrate proposal²⁰ anticipated developing a total of 29 modules (12 Intro, 8 Teacher Prep, 9 reaching outside of geosciences), 9 courses (8 interdisciplinary for geoscience programs, 1 geoscience for non-majors), plus an additional six materials (which might be either modules or courses) emergent from early workshops. The proposal envisioned a total of 44 curriculum development efforts engaging 150 faculty as developers.

The amount of curriculum development work is slightly less than proposed (32 versus 44 materials development efforts, involving 110 versus 150 faculty developers) -- but is still a vast accomplishment. The smaller number of dedicated teacher prep modules resulted from a decision to invest teacher prep effort (after the modules for elementary ed and secondary science methods courses were completed) into nudging mainstream Intro Geo courses into better alignment with the needs of future teachers rather than making more teacher-prep-specific modules.²¹ Throughout the materials development process, few proposals were received from teams wishing to develop materials for upper division geoscience courses, despite efforts to recruit such teams; the Leadership Team made a conscious decision to steer away from upper division materials towards more interdisciplinary materials.²² The course development effort was disproportionately concentrated at one institution (Penn State), rather than being spread across the country.

Quality

The claim that InTeGrate instructional materials are of high quality rests on three lines of evidence: (1) checks and balances built into the development process, including an external review for scientific accuracy, (2) confirmation by an independent peer review process, (3) the vote of confidence expressed by educators who have elected to adopt/adapt and continue to use InTeGrate materials because, in their professional judgment, the materials are effective, and (4) evidence of student learning gains among students taught with InTeGrate materials.

The rubric and audit system described above pushes InTeGrate's instructional materials towards use of evidence-based pedagogical approaches. In order to “pass the rubric” and move on to pilot testing, a course or module had to score 85% or higher on each of the pedagogical sections of the Materials Development rubric as well as 100% on the Overarching Goals (aka Guiding Principles) (Exhibit II-2). The pedagogical sections of the rubric check for the presence of clearly articulated learning goals that relate to geoscience literacy outcomes; assessments that have objective standards and span multiple cognitive levels; instructional materials that are at the appropriate level and depth for the intended audience, and support the stated learning goals; specific instructional strategies that are research-based and student-centered; and alignment among teaching materials, goals, assessments, resources, and learning activities.

The publication template²³ also enforced the inclusion of elements intended to make InTeGrate materials more educative for faculty and easier to adapt. These elements include Teaching Notes and Tips, Instructor stories, a listing of types of courses the module could fit into, and a visual indicator of the level and duration of the module. After initial publication, each course or module was pilot-tested at multiple institutions, and revised following testing. Revision was informed by both the tester/developers'

²⁰ InTeGrate proposal narrative, page 13, table 3.

²¹ Email from Anne Egger, 9 Sept 2018. Also, Egger, A.E., Kastens, K.A., & Turrin, M.A. (2017). Sustainability, the Next Generation Science Standards, and the Education of Future Teachers, *Journal of Geoscience Education*, 65(2), pp. 168-184, DOI: 10.5408/16-174.1

²² Anne Egger, personal communication.

²³ InTeGrate Teaching Materials Format:
https://serc.carleton.edu/integrate/info_team_members/currdev/teacher_format.html

lived experience using the materials, and by student responses to project-wide assessments and to embedded assessments provided by the materials development team.

The final step before publication was a review for scientific accuracy, overseen by the Assessment Team Chair.²⁴ Reviewers were asked: Are the scientific concepts correctly described and applied? Are all essential or core concepts included? Are the data and/or materials up to date? Are there critical missing analyses or flawed analogies? Are the figures and data correct and do they support the curriculum? Are the references correct and appropriate? After addressing reviewers' comments and suggestions, developers wrote a letter similar to what one would write to a journal editor, indicating the changes made in response to the reviews, and final approval of the module was made by the Assessment Team leader after examining the response to the external and technical reviews. Finding qualified and willing science reviewers was challenging, especially for courses, and often delayed publication.

The *On the Cutting Edge* project began a community-driven process of peer review of teaching activities, which is now being continued during “review camps” at each Earth Educators’ Rendezvous. The peer-review process that evaluates teaching activities for this collection is independent of InTeGrate and uses a different rubric.²⁵ To be accepted into the Cutting Edge “Exemplary Collection,” an activity must receive Exemplary or Very Good scores in all five categories of the Cutting Edge rubric, and must have been rated Exemplary in at least 3 of the 5. It is expected that no more than 10-20% of the activities in the collection would be admitted into the Exemplary Collection. As of May 2019, 16 InTeGrate modules had had at least one unit admitted to the Cutting Edge Exemplary Collection, and a total of 40 InTeGrate units had been admitted.²⁶

At most institutions of higher education, instructors have wide latitude to choose the instructional materials they use in their classes, based on their professional best judgment of what would work well with their students and in their instructional context. Thus, an independent line of evidence of the quality of the InTeGrate instructional materials is the decision of large numbers of instructors, across the country, to try out an InTeGrate module and then to continue to use InTeGrate materials. The evidence that InTeGrate materials are being taken up by faculty members who were not involved in their development can be found in Sub-claim 2E, in the next chapter.

A final line of evidence about the quality of InTeGrate’s instructional materials comes from data on student learning and attitudes. This complex data is reviewed below, in Claim 1E.

Scope

Collectively, InTeGrate's materials span a wide range of issues/challenges, target audiences, and geoscience literacies.

²⁴ Birnbaum, S., and InTeGrate Assessment Team (2016). InTeGrate External Science Review—Policies and Procedures, at: https://serc.carleton.edu/admin/private_download.php?file_id=90723 [Restricted access]. Also, personal communication from Anne Egger, Feb 2019.

²⁵ On the Cutting Edge: Peer Review of Teaching Activities: https://serc.carleton.edu/NAGTWorkshops/activity_review.html Materials are reviewed for scientific veracity; alignment of goals, activities, and assessment; pedagogical effectiveness; robustness (usability and dependability of all lesson components); and completeness of the Activity Sheet web page for the activity.

²⁶ May 3, 2019: Searched on https://serc.carleton.edu/serc/search.html?q1=sercvocabs__74%3A11&q2=sercmodulelist__2244 to refine Information type to “course module” and then further refine “location” to InTeGrate.

Egger et al. (2019) analyzed how thoroughly InTeGrate curriculum materials address the suite of critical needs for geosciences as defined by the American Geoscience Institute (2016).²⁷ All of AGI's (2016) critical needs were addressed by the InTeGrate materials, although to different extents. The most thoroughly addressed was "Building resiliency to natural hazards," and the least-addressed was "Providing raw materials for modern society" (Exhibit II-6). AGI's critical needs document was not available when InTeGrate's Materials Development process began, but several precursor grand challenges documents did exist and were made available to developers.²⁸

In addition, the scope of the InTeGrate curriculum materials has been assessed against the Earth & Space Science Disciplinary Core Ideas (DCI's), Science & Engineering Practices (SEP's), and Cross-cutting Concepts (CCC's) of the Next Generation Science Standards (NGSS). Results of this analysis are shown in Exhibit II-7.²⁹ Although the NGSS and its underlying framework target K-12 educators rather than higher education, this comparison is relevant because future teachers typically obtain their Earth Science content knowledge from Intro courses taught in geoscience departments, and because the Framework underlying NGSS constitutes a deeply-researched stance about how science education should be approached. Among the DCI's, the InTeGrate materials provide good coverage of the Earth- (as opposed to Space-) related topics (Exhibit II-7). InTeGrate's minimal coverage of Biogeology³⁰ is a bit surprising, given InTeGrate's commitment to interdisciplinarity. Among the NGSS Practices, InTeGrate stands out for its emphasis on Practice 4: Analyzing and Interpreting Data, and Practice 2: Developing and Using Models. The former is surely an outgrowth of InTeGrate Rubric element 1.4, "use of authentic and credible geoscience data," and the latter likely results from Rubric element 1.5, "incorporates systems thinking" (Exhibit II-2). Among the NGSS Cross-cutting concepts, ITG materials are notably strong in "Patterns," "Cause & Effect," and "Systems & Systems Modeling." Give the importance of "Energy & Matter" in Earth processes, it is surprising that this Cross-cutting Concept is not more strongly expressed in the InTeGrate materials.

²⁷ Identification of critical needs is from: AGI (2016). *Geoscience for America's Critical Needs*. Alexandria, VA. Alignment of ITG curriculum materials with critical needs is from: Egger, A., Bruckner, M. Z., Birnbaum, S. J., & Gilbert, L. A. (2019). Facilitating the development of effective interdisciplinary curricular materials goals. In Gosselin, D.C., Egger, A.E., Taber, J.J., (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 45-68.

²⁸ National Research Council (2001). *Grand Challenges in Environmental Sciences*. Washington, D.C.: The National Academies Press. Zobak, M. L. (2001). Grand challenges in Earth and Environmental Sciences: Science, stewardship, and service for the twenty-first century. Geological Society of America Presidential Address. *GSA Today*, 12, pp. 41-47. Institute, A. G. (2008). *Critical Needs for the Twenty First Century: The Role of the Geosciences*. Alexandria, VA: American Geological Institute. Some InTeGrate materials indicate alignment with these older "challenges" documents on the front page under "Show me more about fitting this material into my course > Show key literacies and societal issues addressed in the module."

²⁹ Egger, A.E., Fox, S.P., McDaris, J.R., and Gilbert, L.A. (2017). Facilitating three-dimensional learning with adaptable, searchable, NGSS-aligned curriculum materials from InTeGrate. *Geological Society of America annual meeting*, paper 235-12. Abstract at: <https://gsa.confex.com/gsa/2017AM/webprogram/Paper306673.html>

³⁰ The guiding question for ESS2.E.Biogeology is "How do living organisms alter Earth's processes and structures?" <https://www.nap.edu/read/13165/chapter/11#189>

“Context of societally important Earth-related problems” and other guiding principles

The InTeGrate Materials Development Rubric includes five guiding principles, which all curriculum materials had to meet before being approved to move on to pilot-testing and subsequent development phases. These are:³¹

1. Course or module must address one or more geoscience-related grand challenges facing society.
2. Course/module develops student ability to address interdisciplinary problems.
3. Course/module improves student understanding of the nature and methods of geoscience and develops geoscience habits of mind.
4. Course/module makes use of authentic and credible geoscience data to learn central concepts in the context of geoscience methods of inquiry
5. Course/module incorporates systems thinking.

The assessment team materials review and auditing system ensured that all published modules aligned with these guiding principles at a fundamental level. Browsing through the web-published instructional materials, or *Part II: Earth & Sustainability across the Curriculum* of the Gosselin et al. (2019) edited volume, shows that there is wide variation in the depth/breadth and instructional strategies with which development teams met these challenges. This richness and variability remains largely unanalyzed. A start in this direction was made by Kastens & Krumhansl (2017), who identified and tallied the use of instructional strategies (aka “design patterns”) that support use of authentic and credible geoscience data (InTeGrate Guiding Principle #4) in the first six Introductory modules published (Exhibit II-8).³² An extensive but not methodical scan of InTeGrate modules by evaluator Kastens found that outside the dedicated “Systems Thinking” module and “Modeling Earth Systems” course, most InTeGrate systems thinking is of the type characterized by Scherer et al (2017)³³ as “Earth System Perspective” (conceptualizing the Earth system as a whole and understanding interconnections between Earth’s spheres, but not discussing specific systems concepts such as boundaries, flux, feedbacks, stocks and flows) or “Authentic complex Earth and environmental systems” (emphasis on student model-based reasoning about a particular real-world environmental system or phenomenon, rather than on developing transferable systems thinking skills.)

Analyses analogous to Kastens & Krumhansl (2017) could be done for the other guiding principles, which could help to support innovative curriculum development in the future. Some strategies for materials developers have been gathered into synthesis web pages on “Teaching Systems Thinking” and “Effective Strategies for Interdisciplinary Teaching.”³⁴ A few examples of instructional strategies used in support of guiding principles other than use of authentic data:

³¹ Steer, D., Iverson, E., Egger, A., Kastens, K. A., Manduca, C. A., & McConnell, D. (2019). The InTeGrate materials development rubric: A framework and process for developing curricular materials that meet ambitious goals. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 25-43.

³² Kastens, K. A., & Krumhansl, R. (2017). Identifying curriculum design patterns as a strategy for focusing geoscience education research: A proof of concept based on teaching and learning with geoscience data. *Journal of Geoscience Education*, special issue on Geoscience Education Research, 65, pp. 373-392.

³³ Scherer, H. H., Holder, L., & Herbert, B. E. (2017). Student learning of complex Earth systems: Conceptual frameworks of Earth systems and instructional design. *Journal of Geoscience Education*, 65(4), pp. 473-489.

³⁴ Teaching Systems Thinking:

https://serc.carleton.edu/integrate/info_team_members/currdev/effective_materials/systems_think.html. Effective strategies for interdisciplinary teaching:

https://serc.carleton.edu/integrate/teaching_materials/interdisciplinary_format.html

- *Use of computational modeling in support of GP #2 (interdisciplinary problem solving):* The “Regulating Carbon Emissions to Mitigate Climate Change” module has students work with the Web-based Dynamic Integrated Climate Economy (webDICE) model, which couples geophysical systems to economic systems. Students “discover” that the uncertainty in climate sensitivity (i.e. the geophysical uncertainty) is small relative to the uncertainty in how changes in climate will manifest as harmful outcomes (the socio-economic uncertainty), and also small relative to the uncertainty of future emissions.³⁵
- *Use of GIS in support of GP #3 (geoscience methods of inquiry):* “The Wicked Problem of Global Food Security” module has students work extensively with an online version of the ArcGIS (geographic information system), first through a guided inquiry on the “Story of my Chocolate Bar,” and then, a collaborative research project on a food (in)security in a region of each group’s choice. Boger, et al. (2019) reflect on the value of GIS in fostering spatial thinking, a foundational mode of inquiry and habit of mind in geosciences: “By bringing datasets together, students learn how to detect spatial relationships... to generate or test hypotheses from visual examination or geo-statistical analyses that reveal patterns.”³⁶
- *Drawing systems maps in support of GP#5 (systems thinking):* The “Changing Biosphere” module teaches a graphic language for systems mapping, and stresses that the purpose of building a systems model is “to help us think about [earth processes] when we are considering scenarios that we have not directly experienced.” With teacher guidance, student groups sketch a systems model for carbon cycling within the permafrost-atmosphere-biosphere system, and then use this model on their own to reason about this system would respond to a catastrophic disruption such as a massive meteor impact or volcanic eruption.³⁷

These examples show faculty developers making ambitious, educative use of the tools of modern science (e.g. research-grade computational models and data analysis software) to implement InTeGrate’s guiding principles—but also use of one of the oldest of pedagogical tools (paper and pencil/marker). Whether high- or low-tech, all of these examples require deep knowledge of Earth processes and geoscience modes of inquiry to create.

Versatility

InTeGrate's instructional materials were intended to be adaptable and to function effectively in different institution types, geographic settings, with different instructors, and different types of students. There is no project-wide objective measure of how well this goal was reached, but the Instructor Stories and publications recount numerous instances where materials were adapted to different contexts and

³⁵ Penny, S. M., Smyth, R., Sethi, G., Leibensperger, E., Gervich, C., & Batur, P. (2019). Interdisciplinary and topical in the science classroom: Regulating carbon emissions to mitigate climate change. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Switzerland: Springer.

³⁶ Boger, R., Low, R. D., & Potter, A. E. (2019). Tackling the wicked problem of global food security: Engaging undergraduates through ArcGIS online. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Springer: Switzerland, pp. 159-177. Association for Environmental Sciences and Studies. Quote is from p. 169.

³⁷ Changing Biosphere > Unit 3: The Interconnected Nature of the Atmosphere, Hydrosphere, and Biosphere: https://serc.carleton.edu/integrate/teaching_materials/biosphere/activity3.html. Quote is from slide 11 of the Unit 3 PowerPoint presentation.

where the instructors or IP leaders report being pleased with the results. A few well-documented examples:³⁸

- Teasdale³⁹ et al. (2019) report numerous examples of how materials were adapted for STEM and non-STEM courses in a related cluster (“pathway”) of courses on sustainability at Cal State Chico. The most dramatic example was how Climate of Change: Unit 6: Adapting to a Changing World was adapted for an introductory Environmental Literacy course, a 200-level Religious Studies course, and a 300-level Plant Science course.
- In the El Paso Higher Education Community, the adaptations often involved shortening a unit to fit the time length of a class or adding place-based materials.⁴⁰ Examples of adding place-based materials include evaluation of water levels in El Paso wells as part of the Environmental Justice and Freshwater Resources module, Unit 2, examining how El Paso might cope with increasing summer heat in Climate of Change Unit 6, and finding out what types of materials can be recycled in El Paso and where, as part of Humans’ Dependence on Mineral Resources, Unit 2.
- In the culminating activity for “An Ecosystems Services Approach to Water Resources,” students apply what they have learned about storm water runoff to evaluate a proposed change in land use, with the goal of making the development “water neutral” through the use of low-impact development techniques. The three faculty testers tailored their implementation of Unit 3 to their three specific locations, using actual proposed or plausible developments on their campuses or in the neighboring community.⁴¹ Such versatility was possible because the module makes use of the EPA’s National Stormwater Calculator, which taps into national databases that provide soil, topography, rainfall and evaporation data for any locale.

Educative

InTeGrate materials incorporate features that are designed to be educative for the faculty using them, such as annotated scoring rubrics, instructor stories, and links to web pages about the pedagogical strategies used. The entire publication model for InTeGrate instructional materials is instructor-facing, with the instructor as the primary audience and student-facing materials embedded within. The inclusion of these educative, instructor-serving features was encouraged/required by the InTeGrate publication template,⁴² and enforced by the team leader and web staff person supporting each development team.

Underlying the educative features in individual instructional units, InTeGrate provides educative web pages about how to implement recommended instructional strategies and overcome known challenges. These are linked within the individual units at the point of use. Some of these (e.g. Effective Strategies

³⁸ See also: Bruckner, M., et al., (2017). Using instructor stories to demonstrate the adaptability of the InTeGrate interdisciplinary sustainability curricula, GSA poster, abstract at: <https://gsa.confex.com/gsa/2017AM/meetingapp.cgi/Paper/300554>

³⁹ Teasdale, R., Hatfield, C., Clements, P., Altir, L., Hankins, D., & Willard, E. (2018). Modified use of InTeGrate curriculum in the Sustainability General Education Program at California State University, Chico. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 277-296.

⁴⁰ Doser, D., & Villalobos, J. (2019). Use of InTeGrate materials to engage instructors and encourage curriculum change in the El Paso Higher Education Community. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer.

⁴¹ Barbanell, E., Jarchow, M., & Ritter, J. (2019). Using ecosystem services to engage students in public dialogue about water resources. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Switzerland: Springer, pp. 179-196.

⁴² Info for Materials Developers > Structuring your Module or Course: https://serc.carleton.edu/integrate/info_team_members/currdev/teacher_format.html

for Interdisciplinary Teaching) were created specifically for InTeGrate while others (e.g. Gallery Walk; Jigsaw) have been carried forward from earlier SERC-supported faculty development efforts.⁴³

The value of the educative features built into the InTeGrate instructional modules has not been evaluated. However, they are built on a long and successful heritage. The publication template for InTeGrate materials derives from the SERC Activity Sheet, which has been in use since the early 2000's. As described by Manduca, et al. (2006), Activity Sheets are designed to steer faculty contributors towards including educative information, including learning goals, context for use, teaching tips, and assessment approaches, and to allow users to efficiently scan through a large collection of resources after gaining familiarity with the standard structure.⁴⁴

Uptake

Many NSF projects produce excellent curriculum materials, but do not achieve widespread uptake outside of the core group of materials developers and testers (Kezar, 2011).⁴⁵ Achieving substantial “market share” in the crowded field of STEM educational materials requires both high quality materials and an effective program of outreach/dissemination/marketing/professional development. The InTeGrate database has data on 3183 course enactments that adapted, adopted, or were influenced by InTeGrate materials, and there are surely additional instructors who have used InTeGrate materials from the web but never filled out any of the project's forms or surveys. Uptake of InTeGrate materials is discussed at length under Claim 2, in the context of documenting the spread of high-quality instructional materials. Here, in the context of Claim 1B, this extensive amount of uptake is also an indicator that faculty members are finding the materials to be of good quality and pedagogically useful.

However, the degree of uptake varies widely across the portfolio of materials. Exhibit II-9 shows the number of enactments for which usage of each InTeGrate module is recorded in the InTeGrate course database.⁴⁶ The graph shows a highly uneven distribution, with some superstar modules being taught hundreds of times, while others have scarcely reached beyond the pilot testing group. There are confounding factors here; for example, the earlier-published materials have had more terms in which to accrue enactments, and some topics are simply taught more often than others. Two strong patterns do emerge: the higher uptake modules are all at the Intro level (Exhibit II-9), and they are all modules rather than full courses (not illustrated). The bottom line here is that the InTeGrate materials development process was capable of producing instructional materials that were judged to be appropriate for adoption/adaptation by large numbers of faculty peers—but not every attempt or every team achieved at this level.

⁴³ Effective Strategies for Interdisciplinary Teaching: https://serc.carleton.edu/integrate/teaching_materials/interdisciplinary_format.html. Gallery Walk: <https://serc.carleton.edu/introgeo/gallerywalk/index.html>. Jigsaws: <https://serc.carleton.edu/introgeo/jigsaws/index.html>

⁴⁴ Web pages about SERC activity sheets: https://serc.carleton.edu/serc/activity_design/sheets.html; also <https://serc.carleton.edu/serc/sheets.html>. Paper describing the rationale behind use of Activity Sheets and other common format resources: Manduca, C. A., Iverson, E., Luxenberg, M., Macdonald, R. H., McConnell, D. A., Mogk, D., & Tewksbury, B. (2017). Improving undergraduate STEM education: The efficacy of discipline-based professional development. *Science Advances*, 3, e1600193.

⁴⁵ Kezar, A. (2011). What is the best way to achieve broader reach of improved practices in higher education? *Innovative Higher Education*, 36(4), 325-247.

⁴⁶ Data from Excel file classroomuse_2018_ks11.2.18.xlsx, provided by Kathryn Sheriff, SERC, November 2018, graph by Kim Kastens. An “enactment” in this data comprises one instructor who reports teaching with materials adapted or adopted from the course or module for one term. This includes use of a partial module or course. Multiple courses by the same instructor (in the same or different terms) are counted as multiple enactments. Multiple modules taught by the same instructor (even in the same course) count towards the tally for each module.

* * * * *

Sub-Claim 1C: Faculty who engage with InTeGrate's materials and associated professional development shift in beliefs and practice towards research-tested pedagogies and teaching about the Earth in the context of societal/environmental issues.

Shift in Beliefs and Practices of Materials Developers

InTeGrate's materials development process was envisioned—and served—as a professional development opportunity as well as a mechanism to create curriculum materials. This opportunity encompassed faculty from 28 states and from all institution types (Exhibit II-10).⁴⁷ One hundred and ten faculty from 84 institutions completed InTeGrate's materials development process, from initial proposal submission, through development and piloting of a module or course, revision, science and technical reviews, and publication of their materials on the InTeGrate website.

Throughout this multi-year process, they engaged in frequent and wide-ranging discussions about teaching and learning, with their team members, Assessment Team consultant, a member of the InTeGrate Leadership Team supervising development for their audience group (Intro, Teacher Prep, Interdisciplinary), at least one SERC staff member, and the students in their pilot course enactments. Multiple lines of evidence suggest that this was a powerful professional development experience for these faculty members. Evidence comes from interviews conducted by external evaluators and researchers, surveys of the Intro module developers, classroom observations of teaching practice, as well as instructor stories, publications, and presentations by materials developers.

As the first two cohorts of materials developers completed their work, external evaluator Carol Baldassari reviewed their written reflections at four points along the development timeline and conducted team interviews and project leader interviews at face-to-face meetings. These findings were detailed in the mid-project evaluation report,⁴⁸ and can be summarized as follows: The first cohort, who began their work in the spring of 2012, viewed themselves as “guinea pigs” or “pioneers” of the InTeGrate process, with many aspects of the development process needing to be ironed out. Yet, even among these early cohorts, most participants found their involvement in InTeGrate's materials development process to be “an intensive personal and professional collaborative learning experience.” A few particularly insightful comments:⁴⁹

- Having goals and objectives formalized forced me to think differently about the design of course. Before, it was chaotic; here's a way to put things together. No one was holding my feet to the fire. InTeGrate's process forces you to think about how to start, where are you going towards. And, it actually gives you a tangible product. I'm thinking about redoing all my classes.
- In the last few years, I have tried to use more interactive activities in my classes, so I jumped at the chance to work with others to develop more of those. Going through [the development] process and thinking through the requirements of InTeGrate gave me a higher standard of what those activities should be; a more specific idea of what those activities should be like and their quality.

⁴⁷ Egger, A., Bruckner, M. Z., Birnbaum, S. J., & Gilbert, L. A. (2019). Facilitating the development of effective interdisciplinary curricular materials. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer.

⁴⁸ Kastens, K. A., Baldassari, C., & DeLisi, J. (2014). InTeGrate: Interdisciplinary Teaching of Geosciences for a Sustainable Future: Mid-Project Evaluation Report. Online at: https://serc.carleton.edu/admin/private_download.php?file_id=75442 [Restricted access]

⁴⁹ Quotes are from Kastens, Baldassari & DeLisi (2014), pp. 7-22.

- As we were revising the module, we added more student reflection. I've been adding it in throughout the semester. I need to do it throughout the whole course. I appreciate that I don't do it often enough.
- The instructor I worked with commented often how thrilled she was about how engaged they [students] were throughout the module and how she didn't realize how much responsibility could be placed on the students to step up, so that indicated to me that this was different than the usual classroom for her...

Teaching beliefs and practices of 21 developers of seven early Intro modules were studied by Michael Pelch and David McConnell.⁵⁰ Teaching beliefs were examined with the Teaching Beliefs Interview (TBI)⁵¹ and the Beliefs About Reformed Science Teaching and Learning (BARSTL) survey.⁵² Data were collected shortly after participants were selected to work on the project, and then again after the team had completed the final revisions of their module. The TBI is a semi-structured interview that probes what the interviewee thinks to be true about how to maximize student learning, the role of a teacher, how to know when a student understands, how to decide what to teach and when to move on to a new subject, how students learn science best, and how to know whether learning is occurring. TBI results are shown in Exhibit II-11. Fifteen out of 21 (71%) of the developers showed gains on their TBI scores from pre- to post-development, five were unchanged, and 1 decreased (Exhibit II-11, upper). TBI scores at the beginning of the development effort had a mean of 25.8, while post-development scores' mean was 28.2, a statistically significant shift. The largest normalized gains were found among the participants who had the lowest initial scores. Of the seven TBI questions, the largest gains were seen on the following questions: How do you decide what to teach and what not to teach? How do you know what your students understand? How do you know when to move on to a new topic in your class? (Exhibit II-11, lower). The BARSTL is a 32-item online survey; each item is a proposition, to which the respondent indicates strongly disagree, disagree, agree, or strongly agree. Fifteen of the 21 developers' BARSTL scores increased, interpreted as a shift away from a perspective that emphasizes the transmission of knowledge from instructor to student, and towards a constructivist view that the individual creates knowledge and it can be unique to each student.

Using the RTOP protocol, teaching practices of ten intro-level InTeGrate module developers were analyzed as they piloted their InTeGrate materials. Trained observers used the RTOP rubric, a 25-item observational protocol, to characterize the level of reformed teaching during a class period. RTOP has been used extensively in geoscience classrooms.⁵³ The data are shown in Exhibit II-12,⁵⁴ and are compared with the mean RTOP score for a nationwide sample of RTOP scores from Intro Geoscience(?) courses. The mean RTOP for the InTeGrate pilot enactments was 52.5 out of 100. Anything over 50 is

⁵⁰ Pelch, M. A., & McConnell, D. A. (2016). Challenging instructors to change: A mixed methods investigation on the effects of materials development on the pedagogical beliefs of geoscience instructors. *International Journal of STEM Education*, 3(5), 1-18. Also, chapter 1 in Pelch, M. A. (2016). Exploring how new teaching materials influence the beliefs and practices of instructors' and students' attitudes about Geoscience. (PhD), North Carolina State University.

⁵¹ Luft, J. A., & Roehrig, G. (2007). Capturing science teachers' epistemological beliefs: The development of the teachers beliefs interview. *Electronic Journal of Science Education*, 11(2), 38-63. Online at: <http://stelar.edc.org/sites/stelar.edc.org/files/7794-26589-1-PB.pdf>

⁵² Beliefs about Reformed Science Teaching and Learning (BARSTL) Survey. Survey is online at: <https://serc.carleton.edu/NAGTWorkshops/careerprep2015/barstl.html>

⁵³ Budd, D. A., van der Hoeven Kraft, K., McConnell, D. A., & Vislova, K. (2013). Characterizing teaching in introductory geology courses: Measuring classroom practices. *Journal of Geoscience Education*, 61, pp. 461-475.

⁵⁴ Unpublished data from David A. McConnell, presented at the InTeGrate Evaluation Summit, 23 May 2018, available at https://serc.carleton.edu/admin/private_download.php?file_id=91293 [Restricted access]

categorized as “Active Learning.”⁵⁵ For comparison, the mean RTOP score for a nationwide sample of 66 intro geology classes taught before the advent of InTeGrate was 41.5,⁵⁶ in the range considered “Active Lecture” and above the range considered “Traditional Lecture” (<30). There was variation in RTOP score between modules, and also between instructors within modules. However, 9 out of 10 of modules had mean scores higher than the non-InTeGrate national sample (Exhibit II-12), as did 19 out of 21 of the individual instructors (not illustrated). These developers were not observed prior to their InTeGrate professional development experience nor while they were teaching with non-InTeGrate materials.

At the end of the project, a purposeful sample of InTeGrate faculty participants was interviewed by external evaluators Lia Wetzstein, Katie Kovacich, and Debra Bragg, including 21 materials developers representing 17 modules.⁵⁷ One of the questions guiding the interviews was “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?” These interviews revealed that almost all faculty made changes to their teaching practices, such as more use of formative assessment, more group work, more real-world case studies, or more emphasis on systems thinking and use of authentic data.⁵⁸ One geoscientist offered a compelling connection between what s/he learned from the InTeGrate process and changes s/he made to teaching:

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.

Of the five guiding principles, interdisciplinary problem solving was mentioned most often, geoscientific thinking was mentioned least often, with the others (systems thinking, authentic data, and environmental grand challenges) seeming to be of intermediate salience in the interviewees responses. But all got some response, as from the geoscientist who said:

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.

Shifts in Beliefs and Practices of ITG Materials Users

InTeGrate Materials Developers spent months or years working on their course or module, including two trips to SERC headquarters and innumerable communications with their Team Leader, an Assessment Team consultant, and SERC staff web consultant. The InTeGrate Materials Development and Revision Rubric was their constant companion through this journey, with its unrelenting insistence on student-

⁵⁵ Classroom Observation Project > Understanding and improving our teaching using the RTOP > How are RTOP scores determined?: <https://serc.carleton.edu/NAGTWorkshops/certop/calculation.html>

⁵⁶ Budd, et al. (2013). *op. cit.*

⁵⁷ Wetzstein, L., Kovacich, K., & Bragg, D. (2017). InTeGrate Faculty Study: Community College Research Initiatives: University of Washington.

⁵⁸ It is difficult to disentangle the extent to which these changes have been incorporated across the interviewees’ entire teaching practice (as contrasted with just using them while teaching with the module or course they developed during their InTeGrate subaward). However, SERC internal evaluator Ellen Iverson has done a comparison of developers’ reflections during the development process, and their interview comments at the time of the end-of-project interviews (multiple months after publication of the modules.) She found that the more ambitious changes to pedagogy and use of guiding principles emerged in the “After Participating” interviews rather than in the “While Participating” reflections, so there is some reason to think that the totality of respondents’ teaching practice has been impacted. Iverson, E. R., & Wetzstein, L. (in press). Connecting learning about the earth to societal issues: Downstream effects on faculty teaching. In J. Ostrow (Ed.), *Teaching about Sustainability across Higher Education Coursework, New Directions for Teaching and Learning, No. 161*. San Francisco: Jossey-Bass.

centered, research-based pedagogical approaches. While it is wonderful that more than 100 faculty from all kinds of institutions had this intensive experience, and that their teaching beliefs and practices changed as a result, most faculty will not have that experience. Project leadership felt a need to know what impact InTeGrate materials have on the teaching practices and beliefs of faculty members who just pick up the InTeGrate materials and teach with them.

Under the direction of Leadership Team members David McConnell and Elizabeth Nagy-Shadman, a quasi-experimental research study was set up, involving eight college instructors from a range of institution types, geographic settings, class sizes, and course foci. Participants were recruited through an open call for proposals, and agreed to insert a minimum of 18 published InTeGrate units⁵⁹ into an existing introductory level course, replacing existing content (Nagy-Shadman et al, in press).⁶⁰ This group of faculty, referred to as the “Research Team” taught their existing classes in Fall 2015 (control semester) and the revised courses using InTeGrate materials in Spring 2016 (pilot semester) and Fall 2016 (treatment semester). The insertion of the pilot semester between the control and treatment semesters was to avoid start-up difficulties related to the first enactment of a newly-revised course as well as Spring-Fall differences in student enrollment. Research team members participated in a 4-day team meeting at the beginning of the study⁶¹ that included some professional development around student-centered pedagogy, and were mentored by team leaders McConnell and Nagy-Shadman during the course revision process.

Data on teaching practices and beliefs were collected during the control and treatment semesters.⁶² Instructors self-reported their teaching practices using the Teaching Practices Inventory (TPI), and classroom teaching was observed by trained observers using the Reformed Teaching Observation Protocol (RTOP). The TPI is a survey on which instructors indicate their use of teaching practices across 8 categories, ranging from in-class activities to the nature of assignments. Five participants were observed during the control semester, and seven were observed while teaching InTeGrate material during the treatment semester, but due to logistical constraints they were not exactly the same instructors. Instructors’ beliefs about teaching, learning and assessment were probed during repeated interviews using a seven-question, semi-structured interview, the Teacher Beliefs Interview. Each participant was interviewed 4 times during the experience, at the beginning of each semester and at the end of the project.

Teaching practices data⁶³ from the Research Team are shown in Exhibit II-13, with the 8 instructors indicated by pseudonyms. No significant change was found in the Teaching Practices Inventory Scores at the end versus beginning of the project (Exhibit II-13, upper panel). The mean RTOP score for

⁵⁹ 18 units of InTeGrate content equaled between 30 and 50% of the courses. InTeGrate content was drawn from the six Introductory modules that existed at the time the Research Team began their work. Each Intro module contained 6 units, so the required 18 units was equivalent to three modules. Instructors chose which units to use, and were not required to use all the units in any given module.

⁶⁰ Nagy-Shadman, E., Rivera, T., Berg, C., Abolins, M., Hansen, W., Nelson, D., . . . Richaud, M. (2018). Faculty experiences using InTeGrate materials. *In the Trenches*, 8(4). https://nagt.org/nagt/publications/trenches/v8-n4/integrating_integrate_faculty_.html

⁶¹ Research Teams Agenda, June 14-18, 2015: https://serc.carleton.edu/integrate/info_team_members/meetings/summer2015_research_agenda.html

⁶² More on observations of the research team is in Czajka, C. D., & McConnell, D. (2019). The adoption of student-centered teaching materials as a professional development experience for college faculty. *International Journal of Science Education*, 41(5), pp. 693-711. For Teaching Practices Inventory, see Wieman, C., & Gilbert, S. (2014). The Teaching Practices Inventory: A New Tool for Characterizing College and University Teaching in Mathematics and Science. *Cell Biology Education*, 13, pp. 552–569. <http://doi.org/10.1187/cbe.14-02-0023>. For RTOP: Sawada, D., & Piburn, M. (2002). Measuring reform practices in science and mathematics classrooms: The reformed teaching observation protocol. *School Science and Mathematics*, 102(October), pp. 245–253. For the Teacher Beliefs Interview: Luft, J., & Roehrig, G. (2007). Capturing science teachers’ epistemological beliefs: The development of the teacher beliefs interview. *Electronic Journal of Science Education*, 11(2).

⁶³ Czajka & McConnell (2019), *op. cit.*

observations during the Treatment semester was 48.1 out of a maximum possible score of 100, significantly up from the Control semester mean score of 36.0 (Exhibit II-13, lower panel). Both control and treatment results are within the range considered “transitional” (RTOP 30-50), but the treatment semester approaches the threshold to “student-centered” classroom (RTOP \geq 50).⁶⁴ The control semester RTOP mean scores were lower than means reported for geoscience classrooms in previous studies [41.5 by Budd, et al. (2013) and 39.6 by Teasdale et al (2017)⁶⁵]. The Research Team treatment semester RTOP mean scores were lower than the mean reported for InTeGrate Materials Developers (compare with Exhibit II-12).

Teacher Beliefs Interview (TBI) data from the Research Team are shown in Exhibit II-14, again, the instructors are indicated by pseudonyms.⁶⁶ Two of the 8 participants had a substantial shift (>6 TBI points) towards higher TBI from the beginning to the end of the project, while four other participants had a smaller shift in the desired direction (<6 points, Dennis, Ellen, Ian, and Sarah) (Exhibit II-14, upper). When the TBI data are disaggregated by interview question (Exhibit II-14 lower), the most substantial shift towards student-centered beliefs occurred on two questions: “How do you maximize student learning in your classroom?” and “How do you describe your role as a teacher?” For example, on the “role of as a teacher” question, Owen’s pre-InTeGrate response focused on information delivery: “My role as a teacher, I think it is to be a conduit of knowledge. I need to make sure that I’m doing a good job, a complete job, in transferring the knowledge that we know.” By his third interview, Owen was attending more to the students’ backgrounds and interests: “I try to make it relevant...I have some of those business majors, pre-nursing, so, I think, people that you want to be interested in...But I can relate that as well to their majors...it will make them be more interested and aware of different consequences of an activity.”⁶⁷

The TBI questions on which the Research Team showed the biggest pre-/post- shifts (Exhibit II-14, lower) in teaching beliefs were not the same questions on which the Materials Developers had shown the biggest shift (Exhibit II-11). Leadership Team member, David McConnell, who co-led both the Research Team and the Intro Materials Development team, noted⁶⁸ that part of the TBI difference lies in two questions related to formative assessment: “How do you know when your students understand?” and “How do you know when to move on to a new topic in your class?” On these two questions, the MD’s shifted substantially from beginning to end of project, while the RT shifted little or not at all, perhaps because the developers had more ownership of the of the embedded assessments.

The Research Team was mentored by Research Team leaders and supported one another as a collaborative group of seven colleagues going simultaneously through the same sustained effort to incorporate InTeGrate units into their course. But what about InTeGrate-associated faculty who did not enjoy such support and mentoring? A view of un-mentored faculty is provided by semi-structured phone interviews done by evaluators Lia Wetzstein and Debra Bragg of the University of Washington Community College Research Initiatives.⁶⁹ Fifteen faculty from 2-yr and 4-yr colleges and universities

⁶⁴ Budd et al. (2018), *op. cit.* Note that Budd et al use the terms “transitional” (for RTOP 30-50) and “student-centered” (for RTOP \geq 50), while on the *Cutting Edge* RTOP website, these ranges are called “Active Lecture” and “Active Learning” <https://serc.carleton.edu/NAGTWorkshops/certop/calculation.html>.

⁶⁵ Teasdale, R., Viskupic, K., Bartley, J. K., McConnell, D., Manduca, C., Bruckner, M., . . . Iverson, E. (2017). A multidimensional assessment of reformed teaching practice in geoscience classrooms. *Geosphere*, 13(2), pp. 608-627.

⁶⁶ Czajka & McConnell (2019), *op. cit.*

⁶⁷ Czajka, C. D. (2018). *Assessing Learning and Teaching across Geoscience Courses and Curricula*. (PhD dissertation), North Carolina State University, Raleigh, North Carolina. Retrieved from <https://repository.lib.ncsu.edu/bitstream/handle/1840.20/35037/etd.pdf?sequence=1> Quotes from pages 15-16.

⁶⁸ Email, David McConnell to Kim Kastens, October 15, 2018.

⁶⁹ Wetzstein, L., Kovacich, K., & Bragg, D. (2017). InTeGrate Faculty Study: Community College Research Initiatives: University of Washington. Unpublished report for SERC.

were selected from the SERC database of people who had participated in short InTeGrate events such as webinars, workshops or the Earth Educators' Rendezvous, but were not part of a sustained formal InTeGrate team or program. One section of the interview protocol probed for the respondents' approach to teaching and how their methods and materials for teaching and assessment had changed since their InTeGrate engagement. Not all respondents were using InTeGrate instructional materials, but those who were spoke evocatively of changes in their instructional approach and priorities:

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.

...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.⁷⁰

Instructional practices as a function of amount of InTeGrate involvement

This section looks at the relation between dosage of exposure to InTeGrate ideas and teaching practices. The idea is that more InTeGrate exposure would be associated with more reformed teaching practices, more alignment with the InTeGrate Guiding Principles, and more tendency to teach in the context of societal issues.

An online national survey of geoscience faculty teaching practices was conducted in 2004, 2009, 2012, and 2016.⁷¹ This survey began as part of the evaluation of the *On the Cutting Edge* program and has continued under the auspices of the National Association of Geoscience Teachers. Some items were added to the 2012 survey to probe aspects of teaching practice that InTeGrate was emphasizing, and then additional InTeGrate-oriented items were added for the 2016 administration.

Using data from the SERC data base, survey respondents were classified by their degree of InTeGrate (ITG) involvement into four categories:

- No ITG record (n=2201)
- ITG Asynchronous Participant (n=166): this person has a record in the ITG database, but has no record of having attended a webinar, workshop, or other event. Such a person may have joined an interest group, or downloaded materials from the ITG teacher stash, or similar minor interaction that does not involve real-time interaction with community members.
- ITG Synchronous Participant (n=187): this person was a participant, presenter, or leader of a workshop or webinar, or a designated participant from a Rendezvous 2015 workshop.
- ITG SuperParticipant (n=61). This person has had a sustained and influential involvement in InTeGrate, for example as a member of the Leadership Team, an Implementation Team leader, or a module developer.

Eight items on the 2016 survey that were considered to be indicative of "teaching about the Earth in a societal context" were analyzed by degree of InTeGrate involvement.⁷² For items given in multiple years,

⁷⁰ Wetzstein, et al. (2017), *op. cit.* Quotes from pages 14-15.

⁷¹ National Geoscience Faculty Survey: https://serc.carleton.edu/NAGTWorkshops/CE_geo_survey/index.html
Also, Manduca, C. A., Iverson, E., Luxenberg, M., Macdonald, R. H., McConnell, D. A., Mogk, D., & Tewksbury, B. (2017). Improving undergraduate STEM education: The efficacy of discipline-based professional development. *Science Advances*, 3, e1600193.

⁷² Kastens, K.A., and Mara, Vali. Relationship between InTeGrate involvement and responses to NAGT survey items pertaining to teaching about the Earth in the context of societal issues. Online at: https://serc.carleton.edu/admin/private_download.php?file_id=150192 [Restricted access]

the analysis also considered whether the repeated surveys showed that movement towards teaching in a societal context increased during the years when InTeGrate was actively offering professional development to geoscience faculty (2012 to 2016). Respondents cast their answers in terms of a specific course they had taught recently, and responses pertaining to Intro courses were separated from responses pertaining to Majors' courses for analysis.

Of the questions that were asked on repeated surveys, there was **not** movement across time towards teaching in a societal context on five questions that probed: whether students work on a problem of interest to the local community (Q18_3), whether in the last two years the instructor had increased emphasis on environmental issues (Q25_6) or added content linking geoscience to societal issues (Q25_7), whether the instructor frequently communicates with colleagues about preparing students for life on a finite planet (Q35_4), and whether the use of online resources in the last two years has increased the instructor's ability to connect teaching to societal issues (Q39_1). The repeated-surveys data need to be interpreted with caution because there were differences in recruitment approaches, with more outreach to 2YC's in later years.

There **was** a distinctive trend across time on the question that asked "In your most recent [Intro/Majors] course, did your students address a problem of national or global interest?" (Q18_2). For both Majors and Intro students, there was a steady rise in percentage of faculty respondents checking this box from 2004 to 2009 to 2012 to 2016 (Exhibit II-15). There was not a kink upwards in the InTeGrate era. When 2016 respondents are disaggregated by level of InTeGrate involvement, the respondents with no ITG record, asynchronous participants and asynchronous participants clump together on the established trend line. ITG SuperParticipants, on the other hand, stand well off and above the trendline.

For the societal context items on the 2016 survey, there was **not** a systematic relationship between ITG involvement level and teaching practices on three questions: whether students worked on a community-inspired research or service project (Q18_5), whether students make explicit connections from course content to their lives (Q21_7), and whether instructors had increased their emphasis on environmental issues in the last two years. However, there **was** a distinctive pattern on four other questions (figure Exhibit II-16, top two rows), probing: whether students address a problem of national or global interest (Q18_2), whether instructors had in the last two years added content linking geoscience to societal issues (Q25_7), whether instructors frequently communicate with colleagues about how well we are preparing students for life on a finite planet (Q35_4), and whether use of online resources has positively impact respondent's ability to connect their teaching to societal issues (Q39_6). On these questions, the ITG Superparticipants (in other words, Leadership Team, IP Leaders, materials developers), stood well above all the other ITG involvement categories, especially with respect to their Intro courses. There was not a consistent trend across ITG involvement in the other categories, just this one category elevated above all the others.

The 2016 survey also introduced a group of questions about teaching Systems Thinking, an aspect of teaching about the Earth included in InTeGrate's Guiding Principles.⁷³ This same distinctive pattern--of SuperParticipants standing well above all other ITG involvement categories-- was also seen on three systems thinking questions (Exhibit II-16, bottom row): Q25_9 (increased emphasis on systems thinking in last 2 years, intro and majors), Q20_2 (analyze feedback loops, intro and majors), and Q20_1 (discuss a change that has had multiple effects throughout a system, majors only).

It is not clear to what extent the ITG SuperParticipants were already committed to teaching about the Earth in a societal context and thus were drawn to find kindred souls in the emerging InTeGrate effort versus to what extent they evolved into that stance through interactions within InTeGrate. Probably both

⁷³ Kastens, K. (2018). Relationship between InTeGrate involvement and responses to "Systems Thinking" items on the 2016 NAGT national survey of geoscience faculty. Unpublished report available at: https://serc.carleton.edu/admin/private_download.php?file_id=138312 [Restricted access]

were true to some extent. In any case, it seems that as of Spring 2016 (when the courses reflected in the Fall 2016 survey administration would mostly have been taught), this approach was well established within the project's most committed and involved participants--but perhaps had not yet taken root among faculty who merely participated in InTeGrate professional development opportunities or accessed InTeGrate materials online. When course planning for Spring 2016 was underway, only nine InTeGrate modules, and no courses, had been published (Exhibit II-17). The webinar PD program had been running for one year (since Feb 2015), and there had been one Earth Educators' Rendezvous (UC Boulder, 2015). The other 23 courses or modules were in various stages of development, testing, or revision, and thus their materials developers would have been deeply immersed in InTeGrate's rubric and value system. The Leadership Team had been working together and exchanging ideas for four years, since the project launch in Dec 2011.

The 2020 faculty survey will be an opportunity to test to what extent InTeGrate's impact spread outward from the most committed and sustained InTeGrate devotees to individuals touched more lightly by InTeGrate's influence. Spread of InTeGrate's ideas is further discussed in the context of "diffusion of innovation" theory under Claim 2E, next chapter.

* * * * *

Sub-Claim 1D: InTeGrate has developed infrastructure for collaborative, distributed assessment of student learning, as well as instruments to measure students' geoscience literacy, attitudes towards Earth-related issues and careers, and their ability and motivation to contribute to solving environmental grand challenges.

Assessment strategy

The InTeGrate proposal promised⁷⁴ that "... the assessment team will... guide the development teams in embedding assessments that will allow monitoring of student's progress towards learning goals suitable for the project. These assessments will allow the development team to understand when materials are succeeding and the challenges to developing literacy. The assessment team will also guide the development teams in making use of appropriate summative measures that will allow us to measure the impact of materials across the project. A variety of existing instruments will be used... The assessment team will select from and build on these instruments to create a suite of measures that specifically address the project goals of increasing students' geoscience literacy, understanding of the process of science, and interdisciplinary problem solving ability." Moreover, "the evaluation team will analyze assessments of student learning, the same pre- and post-instruction assessments developed and deployed by the assessment team during their review of the effectiveness of modules. However, the evaluation team will take a cross-institutional, project-wide view of these data." And finally, "To evaluate the project's effectiveness at achieving 'significant progress towards addressing the national challenge of environmental sustainability' (NSF, 2010, p. 6), the evaluation team will consider students' ability and motivation to use insights from geosciences to address grand challenges of sustainability. Motivation will be assessed by including a career interest component on pre- and post-instruction surveys of selected students, probing their desire to enter a variety of careers in which insights from geosciences are used to address problems related to sustainability."

In the early months of the project, the Leadership Team, internal and external evaluation teams, and the newly formed Assessment Team made a major, collaborative effort to design an assessment system that could deliver on these ambitious promises.⁷⁵ The system of assessments agreed upon is shown

⁷⁴ InTeGrate proposal, pages 10-11. Reference to NSF (2010) refers to the NSF Solicitation for the STEM Talent Expansion program.

⁷⁵ Evaluator's contemporaneous notes; May 2012 Meeting> Assessment Working Group Agenda: https://serc.carleton.edu/integrate/info_team_members/assessment_team_work/agenda.html [Restricted access]

schematically in Exhibit II-18. Each component is discussed in more detail in the sections that follow. *Formative and Summative assessments* are designed by the materials development team, are unique to each module or course, and gauge learning relative to the stated learning goals and objectives of the course or module. The *Geoscience Literacy Exam (GLE)* is a multiple-choice test used project-wide to gauge students' knowledge of basic ocean, atmosphere, climate, and solid earth science concepts. InTeGrate developed two project-wide *short-essay questions*: one on systems thinking and one on interdisciplinary problem solving. These two constructs were chosen as a proxy for the student's ability to contribute to the solution of grand challenges of environmental sustainability. The *InTeGrate Attitudinal Instrument (IAI)*, an online survey, was developed to capture demographic data, as well as to probe students' motivation towards environmental issues and earth-related careers. *Faculty-submitted forms and surveys* provided context for the learner data, including the course level, class size, format, and reflections on how the materials were used or modified. As it turned out, InTeGrate was not able to find suitable existing instruments for any of its desired data types. All of these assessments were developed by the project, although some, especially the IAI, drew or modified items from prior instruments.

The initial design of InTeGrate's assessment strategy also included a measure of student engagement. Pilot testers were directed to decide on a per-student measure of student engagement, and provide that measure for every student via a spreadsheet. Attendance was the recommended measure. However, if attendance was not taken in that course, pilot testers could provide "another high-frequency measure, such as percentage of assignments completed."⁷⁶ However, the Assessment Team found it impossible to reliably combine the disparate forms of engagement data into a project wide metric and so in the end that data was not used in project evaluation.⁷⁷

Development of collaborative, distributed system for student assessment

One of the critiques of discipline-based education research, including geoscience education research, is that so many of the studies are carried out in one or a few institutions, and thus the generalizability of the findings is suspect.⁷⁸ The technical and social engineering done by the Assessment Team and SERC technical and supporting staff to implement InTeGrate's project-wide assessment system have laid the groundwork for future studies of a nation-wide student population. The challenges to be overcome included: gaining and documenting IRB approval at all participating institutions, protecting student anonymity while retaining the ability to associate and combine/compare multiple student products from the same student, motivating instructors and students to submit data, gathering student responses and student products for a wide range of assessment types, scoring responses to non-short-answer questions in a fair and consistent manner, archiving student responses and scores, providing access to desired data to researchers, ensuring that data are analyzed using good practices.

IRB: Carleton College Institutional Review Board for Human Subject Research (IRB) approved the InTeGrate project as exempt, as research conducted in established or commonly accepted educational settings, involving normal educational practices. But for those data-collecting institutions that have an IRB, those additional IRB's also had to approve, and at all institutions either signed student consent or implied consent had to be obtained. As most participating faculty had little to no prior contact with IRB procedures, the SERC office engaged in considerable professional development around IRB, providing

⁷⁶ For Team Members > Info for Materials Developers > Collecting Data in Your Classroom: https://serc.carleton.edu/integrate/info_team_members/currdev/course_status.html

⁷⁷ Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O'Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp. 91-119.

⁷⁸ Singer, S. A., Nielsen, N. R., & Schweingruber, H. A. (2012). *Discipline-based education research*. Washington, D.C.: National Academy Press.

web materials, example forms, and customized advice. The signed consent forms, for institutions requiring signed consent, or a list of students who had opted out, for institutions that allowed implied-consent, were all submitted to and archived at SERC.⁷⁹

Preserving student anonymity: Each student product and score was marked with a student ID, most often the student's university ID number. As soon as the data was received at SERC, the student ID was converted, algorithmically, into a different number that could not be tracked back to student, but would allow multiple student products to be associated with each other. There were no known instances in which student privacy was breached.⁸⁰

Gathering student responses: InTeGrate's Materials Development Rubric encourages assessments that "vary in type and duration," and that assess "higher order thinking, application of knowledge and even knowledge creation."⁸¹ Inevitably, this meant that student products came in many shapes, sizes and forms, including essays, posters, concept maps, lesson plans, presentations, and computational models. InTeGrate welcomed spreadsheets with student scores and IDs, electronic files (e.g. Word files of student writing, PowerPoints from student presentations, scans of student handwriting or drawings), and paper photocopies of student paper responses. Substantial investment of staff time was required to nudge and cajole faculty to send in their data. Substantial student intern and data archivist time was required to put InTeGrate ID's on everything, scan non-digital entries, and file each entry properly in a secure database. At times this labor-intensive process was a bottleneck that held back the process of data analysis and thus the information flow of formative insights back to the materials developers.

Scoring student responses: The Assessment Team scored a sample of responses to the two project-wide essay questions, as well as a sample of formative or summative assessment responses for each module or course. Each analyzed response was scored by two independent scorers, according to a rubric; where scores disagreed, resolution was achieved by discussion. This labor-intensive process overwhelmed the Assessment Team at times, and an outside consultant was brought in as an additional scorer. To enable the double-scoring process and reliable capture of scores, SERC's technology team build a set of web-accessed tools for scorers (Exhibit II-19). The scoring workload was divided up among the scorers. For each of his/her assigned students, the scorer saw the item prompt, the student response, and a field into which to input a quantitative score and comments, and could access the item rubric upon request.

Providing access to desired data to researchers: In keeping with InTeGrate's goal to build evaluative and assessment capacity among Earth and environmental educators nationwide, InTeGrate student data was analyzed by many different hands. The Assessment Team analyzed student data to provide rapid formative feedback to materials developers and to improve assessments. Various interest groups (e.g., IP teams, materials development teams, the InTeGrate research team, HBCU research team) analyzed data from the students they had taught. SERC and the Evaluation Team analyzed project-wide data for project reporting and evaluation. Each group needed access to different subsets of data. The SERC technical team built web-accessed tools that exported selected subsets of data upon request.⁸² Using check-boxes, the researcher could choose course demographics, student demographics, pre- and post-instruction IAI data, pre- and post-instruction GLE data, and other data types unique to a specific course or module. The

⁷⁹ For Team Members > Info for Materials Developers > Collecting Data in your Classroom:
https://serc.carleton.edu/integrate/info_team_members/currdev/course_status.html#before

⁸⁰ Sean Fox, email, Feb. 14, 2019.

⁸¹ Guidance: InTeGrate Curriculum Development and Refinement Rubric. Downloadable from
https://d320goqmya1dw8.cloudfront.net/files/integrate/info_team_members/currdev/documents/integrate_curriculum_developme.v10.docx

⁸² Access to student data export tool is at:
https://serc.carleton.edu/admin/assess/data_dump.php?project_module_id=2244 [Restricted access]

system would then create a customized csv file containing the data types specified, organized one row per student, with pre- and post-instruction responses paired.

Data analysis using good practices: Although most faculty making use of InTeGrate data are quantitatively literate, many do not have training in statistical analysis techniques used in educational research. Throughout the reporting pages and in talks given by groups of InTeGrate-using faculty, there are quite a few instances of less-than-best-practices in data analysis, such as basing claims on very small sample sizes or small pre-/post- changes. A good model to emulate in future distributed data-analysis efforts can be found in a sister project, the National Geoscience Faculty Survey,⁸³ which has offered professional development webinars on relevant statistical techniques and one-on-one statistical consultations for team members preparing manuscripts using project data.

Despite the nationwide reach and carefully constructed technical and social infrastructure, InTeGrate struggled to get large sample sizes for the project wide assessments. Exhibit II-20 shows the number of students, for each module or course, who gave informed/IMPLIED consent and also submitted at least one assessment (pre/post IAI, pre/post GLE, essays, and/or summative assessment).⁸⁴ On average, there was data from 124 students available for evaluation from each module or course. However, the distribution is highly uneven. Five of the 32 courses/modules contributed data from fewer than 50 students, and half (16/32) of the materials had data from fewer than 80 students. Moreover, many of the individuals included in Exhibit II-20 provided only some of the requested assessments. Problems that seem to have contributed to incomplete data included difficulty obtaining IRB clearance and/or student consent in time for pre-instruction data collection, confusion by the pilot testers on when to administer surveys or what data to submit to SERC, uneven enthusiasm on the part of instructors for pushing students to complete surveys, rules at some institutions against providing credit for survey completion, absenteeism on testing date, and busy/uninterested students.

Summative and Formative Assessments specific to Instructional Modules

As required by the Materials Development Rubric, all InTeGrate instructional materials provide formative assessments to guide the instructor, and a summative assessment that is explicitly designed to measure progress towards the material's overall learning goal(s). Learning goals, in turn, are required to include measurable geoscience literacy goals. Suggested forms for the summative assessment included an essay question, lab report, writing assignment, class project, or concept map designed to show holistic, higher order learning. Whatever the form of the summative assessment, developers were required to provide a rubric for faculty to use in scoring. During pilot testing, the summative assessments were required to be used in the same fashion in all classes testing that course or module.⁸⁵

The first cohort of materials developers (2012) was required to submit a formative assessment for review by the Assessment team. This method did not adequately measure the overarching module/course level goals, so beginning with the second cohort of materials developers (those beginning in 2013 or later), pilot test instructors submitted ungraded copies of individual student responses to the summative assessment to the project. Two Assessment Team members reviewed the assessment itself and the student responses, and provided written guidance to the developer team. These reviews followed a rubric that covered both: (a) how well the assessment itself addressed the module/course goals and the overarching InTeGrate guiding principles, and (b) how well the students appeared to be making progress towards

⁸³ National Geoscience Faculty Survey: https://serc.carleton.edu/NAGTWorkshops/CE_geo_survey/index.html
National Geoscience Faculty Survey Research Group Workspace:
https://serc.carleton.edu/NAGTWorkshops/baseline_survey/index.html [Restricted access]

⁸⁴ Data compiled by K. Sheriff, SERC, and posted at:
https://serc.carleton.edu/admin/private_download.php?file_id=221250 [Restricted access]

⁸⁵ For Team Members > Info for Materials Developers > Working with you Assessment Consultant:
https://serc.carleton.edu/integrate/info_team_members/currdev/assessment.html#sum

meeting those goals and principles, based on their responses to the assessment. Examples of Assessment Team feedback are provided in Exhibit II-21. In follow up conversations with the development team, the assessment consultants discussed both how to improve the assessments and how to improve learning weaknesses revealed by the assessments.⁸⁶

Geoscience Literacy Exam (GLE)

A Geoscience Literacy Exam (full-GLE) has been developed, which includes short-response and essay questions for all of the Geoscience Literacy Principles.⁸⁷ For each of the 30 “big ideas” in the geo literacy documents, the full-GLE includes three questions, at successively higher levels of challenge. Level 1 items are single-select multiple choice questions at the “Remember” and “Understand” level of Bloom’s taxonomy.⁸⁸ Level 2 items are “select all that apply” multi-select questions at Bloom’s levels of “Understand” through “Analyze.” Level 3 items call for short essay answers at the Bloom’s levels of “Analyze through Evaluate.” The items were developed by the InTeGrate Assessment Team, and sent out for review by content experts and assessment experts.

It was intended that individual materials development teams could choose a subset of the full-GLE items that best matched the content they were teaching. However, to obtain a uniform measure of geoscience literacy across the project, a subset of 8 items was selected, which all materials development pilot tests were required to include in their pre- and post-instruction student assessments. This subset, called the GLE-8, or the GLE Common Eight, includes two items from each of the 4 geo literacy documents (Solid Earth, Atmosphere, Climate, and Oceans), one item at level 1 and one at level 2.⁸⁹ A sixteen-item variant of the GLE (called the GLE-16) was developed for use by the Research Team. It included the GLE-8, 5 additional items from the full-GLE, and 3 items from the Geoscience Concept Inventory,⁹⁰ and had a stronger emphasis on solid Earth topics than the GLE-8.

Item difficulty (classical test theory-CTT and item response theory-IRT), answer distribution, distractor analysis was examined. The GLE-8 questions passed validity and reliability testing, while the other tested questions appear promising.⁹¹

⁸⁶ Assessment Team Workspace > Grading Feedback:

https://serc.carleton.edu/integrate/info_team_members/assessment_team_work/June_grading.html [Restricted access]

⁸⁷ Geoscience Literacy Exam (GLE): <https://serc.carleton.edu/integrate/about/gle.html>. Items are at https://serc.carleton.edu/integrate/info_team_members/currdev/documents/gle/index.html [Restricted access] or in the Appendix of Iverson et al. (2019).

⁸⁸ Bloom, B. S., Engelhart, M., Furst, E. J., Hill, W. H., & Krathwohl, D. R. (1956). *Taxonomy of educational objectives: The classification of educational goals. Handbook I: Cognitive domain*. New York: David McKay.

⁸⁹ Figure 2 in Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O’Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp. 91-119.

⁹⁰ GLE-16 is described in Czajka, C. D. (2018). Chapter 2: Can teaching the geosciences in the context of societal issues have an impact on student geoscience literacy gains? In *Assessing learning and teaching across geoscience courses and curricula*. (PhD dissertation), North Carolina State University, Raleigh, NY. Downloaded from https://repository.lib.ncsu.edu/handle/1840.20/24/browse?rpp=20&offset=40&etal=-1&sort_by=1&type=discipline&value=Marine%2C+Earth+%26+Atmos+Sciences&order=DESC. Geoscience Concept Inventory: see Libarkin, J. C., & Anderson, S. W. (2006). Development of the Geoscience Concept Inventory. *Proceedings of the 2006 National STEM Assessment Conference*, pp. 68–80.

⁹¹ Steer, D. N., Iverson, E.A., and Manduca (2013). Piloting a Geoscience Literacy Exam for Assessing Students’ Understanding of Earth, Climate, Atmospheric and Ocean Science Courses, AGU Fall Meeting. Online at: <http://adsabs.harvard.edu/abs/2013AGUFMED32A..02S>.

Essay questions

Students' *ability* to contribute to solving environmental grand challenges was operationalized into two constructs: systems thinking and interdisciplinary problem solving. Essay questions were developed and tested for each of these constructs (Exhibit II-22).⁹² The challenge in creating these essays was to find probes that would be applicable across a wide range of topics and would yield information about student competency in any kind of undergraduate course, spanning both majors and non-majors. In addition, the probes had to be fairly quick to administer and to score. Two operational decisions helped with this assessment challenge: deciding that the essay questions would be given post-instruction only (which eliminated the lowest end of the potential competency range) and deciding that the rubric would be provided to the students along with the prompt (which cut down on the number of completely off-base and hard to score responses).

The process of developing the essay questions used an iterative community approach in which student responses to the essay questions from pilot-testing classes were scored against a rubric by multiple scorers from the Assessment Team. The first version of the Systems thinking prompt yielded weak and inconclusive student responses. Parallel efforts were then made to improve systems thinking instruction (via professional development and materials development) and to develop a more effective assessment for systems thinking. Two additional systems thinking prompts were developed and piloted, with responses gathered in InTeGrate classes, in programs thought to have strong systems thinking instruction, and from expert geoscientists. After analysis of this data, the final systems thinking essay prompt was finalized in time for use beginning in Fall 2014.⁹³

InTeGrate Attitudinal Instrument (IAI)

To probe students' degree of motivation to tackle environmental grand challenges, InTeGrate developed an online attitudinal survey, building upon previously existing instruments.⁹⁴ Both pre-instruction and post-instruction forms ask about students' likelihood of selecting various college majors, interest in various careers, concern about various environmental issues, and engagement in various sustainability supporting behaviors (Exhibit II-23). The pre-instruction form also collects demographic information and asks for the respondent's reason for taking the course. The post-instruction form also asks what influences the respondent's decisions about engaging in sustainability behaviors, how their interest in Earth-related careers and motivation to contribute to creating an environmentally sustainable society changed from beginning to end of the course, and whether/how they can envision using what they learned in this course to help overcome environmental problems.

The process of developing the IAI⁹⁵ capitalized on both the expertise of InTeGrate community members and knowledge from across the broader geoscience community. The items for the IAI were

⁹² About this project > Assessment and Evaluation > Essay Assessments: Interdisciplinary and Systems Thinking: <https://serc.carleton.edu/integrate/about/essays.html>

⁹³ Further detail on the essay development process is at <https://serc.carleton.edu/integrate/about/essays.html> and in Iverson et al. (2019). Analyses of early systems thinking data is Olson, T., and Egger, A., Analyzing student responses from the Geoscience Literacy Exam, linked from https://serc.carleton.edu/integrate/info_team_members/research/index.html [Restricted access], and also in Caulkins, J. L., Steer, D., Iverson, E., Manduca, C., Savina, M. E., & Awad, A. (2014). Student learning in Geoscience courses incorporating societal issues and grand challenges facing society. *Geological Society of America Abstracts with Program* (11-3). Notes from November 2014 meeting of Assessment Team where final system essay was adopted are at: https://serc.carleton.edu/integrate/info_team_members/meetings/Assessment_Agenda_Nov2014.html [Restricted access].

⁹⁴ The InTeGrate Attitudinal Instrument (IAI): <https://serc.carleton.edu/integrate/about/iai.html>

⁹⁵ Further detail on the process of developing and testing the IAI, including links to earlier instruments drawn upon, is at: About this project > Assessment & Evaluation > The InTeGrate Attitudinal Instrument: <https://serc.carleton.edu/integrate/about/iai.html>. See also: Iverson et al. (2019), *op. cit.*

developed through a process of selecting, vetting, and testing items by the external evaluation team in collaboration with the InTeGrate leadership team, and involved a subcommittee of the assessment team. The evaluation team adapted question items related to college majors from a survey developed for the Opportunities for the Advancement of Diversity in the Geosciences program (Fuhrman, n.d.). The list of career aspiration items were adapted from items from both Houlton (2010) and the American Geosciences Institute (2009). For the items related to environmental motivation, the team considered items from a range of assessment and survey instruments in order to develop a set that aligned with the needs of InTeGrate.

Assessment capacity

InTeGrate worked to build assessment and evaluative capacity across the Geo-Ed community, trying to deepen faculty's ability and propensity to use research-tested approaches to formative and summative assessment of student learning, and then use evidence-based decision-making to improve the assessed instructional materials. Groups that had substantial opportunities to increase their assessment capacity included the: Assessment Team, materials developers, Research Team, HBCU working group, and Implementation Program leaders and team members.

The *Assessment Team* members were competitively selected, by application, on the basis of having expertise in assessment as well as in geoscience. They had opportunities to increase their assessment expertise by interacting with each other as a community of practice, by evaluating the pilot-test assessments and student products, by co-creating and refining assessments for the difficult constructs of systems thinking and interdisciplinary problem solving, and by coaching the materials developers on assessment practices. Fourteen geoscientists, from across the country,⁹⁶ now have this deepened assessment expertise coming out of their Assessment Team membership, which would have not have happened if InTeGrate had contracted for professional assessment expertise rather than growing it from within the community. Hunger for this experience is apparently strong in the Geo-Ed community: there were over 75 applications for fewer than ten slots on the Assessment Team.⁹⁷

Materials Developers had to pay attention to assessment of student learning, as they were required to accrue 13 out of 15 points on the Assessment & Measurement section of the Materials Development Rubric (Exhibit II-2). Materials Developers were coached by the Assessment Team on the development of assessments and the use of assessment responses to improve teaching. Iverson et al. (2019),⁹⁸ explore in some detail the rationale and implementation of the system in which the Assessment Team took responsibility for coaching their teams towards high quality materials, *plus* auditing the quality of instructional materials, *plus* scoring student assessments, *plus* providing feedback on assessment effectiveness and student learning to the materials developers. Another project might have insisted on an arms-length relationship between the quality-coaches and the quality-judges. However, InTeGrate chose a community-based, iterative, development-evaluation approach, and Iverson, et al. make the case that

⁹⁶ About this Project > Project Team > Assessment Team:

https://serc.carleton.edu/integrate/about/assessment_team.html, plus meeting notes from annual face to face meetings. The leadership for the Assessment Team was David Steer (founding chair), Stuart Birnbaum (subsequent chair), and Ellen Iverson. Members across all project years included: Leilani Arthurs, Aida Awad, Barbara Bekken, Susan Buhr Sullivan, Joshua Calkins, Wendy Harrison, Megan Plenge, Sian Proctor, Mary Savina, Karen Viskupic, Emily Geraghty Ward. Approximately 10 were active at any one time.

⁹⁷ A small core of Assessment Team members was assembled by invitation, and the rest were chosen from among 75 applicants who responded to an open call. Source: email from Kristin O'Connell, SERC, 6 May 2019. Perhaps related, the call for members of the research team for the NAGT faculty survey was also greatly oversubscribed.

⁹⁸ Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O'Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp. 91-119.

this approach made it possible for InTeGrate to create both strong curriculum materials and strong summative assessments on a short timescale--while at the same time helping the materials developers increase their skill at creating and using assessments.

The *Research Team* was comprised of faculty who agreed to teach the same course without InTeGrate materials, and then twice with InTeGrate materials, and to collect and collaboratively analyze a suite of student assessment data under the mentorship of two members of InTeGrate's Leadership Team. Most Research Team members had little to no experience with educational research. The project helped some of them transition from viewing student assessment responses as merely an accountability device for grading individual students in their own classes, to data that can be used to make inferences about teaching and learning.⁹⁹

The *HBCU Research Team*¹⁰⁰ involves approximately 20 faculty members at Historically Black Colleges and Universities who are teaching with InTeGrate materials and collecting student data. These testers were supported through a webinar-based professional development program. These data are being analyzed by the HBCU Research Team leads, who are collaboratively scoring student products to lay the groundwork for improving teaching about the Earth at HBCU's, mentored by members of InTeGrate's Leadership Team. This effort is still in progress as of February 2019.

Implementation Programs were required to develop an evaluation plan, including collection and analysis of student learning outcome data, before they were admitted to the program. Many struggled with this task, and InTeGrate provided coaching by members of the internal and external project Evaluation Teams and Advisory Board.¹⁰¹ A handful of potential teams did not make it through this process, but in the end, the leadership of all 16 IP teams did design a substantive evaluation plan. In their published program models, 10 of the 16 IPs include student outcome data and discuss it in the context of program improvement or improvement of teaching and learning.¹⁰²

There is no project-wide measure or set of observations that can document the extent to which faculty involved with InTeGrate increased their assessment capacity. Available evidence comes from reports, papers, and reflections from materials developers. For example:

- In the pilot version of the semester-long, upper-division Critical Zone Science (CZS) course, the developers used all of InTeGrate's project-wide assessments (GLE, IAI, and two essays) and had a research paper as their summative assessment. Dere et al. (2019) reflect thoughtfully on the ways in which this suite of assessments initially did not tell them what they wanted to know:

⁹⁹ For Team Members > Faculty Research Team:

https://serc.carleton.edu/integrate/info_team_members/faculty_research/index.html [Restricted access], and team member reporting pages linked therefrom. Evaluator Kastens attended the Research Team data analysis meeting March 2017: https://serc.carleton.edu/integrate/info_team_members/meetings/march17_agenda.html. Some Research Team data was presented as: Rivera, T., [and all other Research Team faculty] (2017). Do InTeGrate materials increase scientific understanding among women? Poster presented at the Earth Educators' Rendezvous: https://serc.carleton.edu/earth_rendezvous/2017/program/posters/wednesday/174533.html.

¹⁰⁰ HBCU Research Team members:

https://serc.carleton.edu/integrate/info_team_members/hbcu_testers_team/index.html. Webinars for HBCU module testers: https://serc.carleton.edu/integrate/info_team_members/hbcu_testers_team/webinars.html. HBCU Research Team Workspace: https://serc.carleton.edu/integrate/info_team_members/hbcu_testers_team/workspace/meetings.html (restricted access)

¹⁰¹ Leadership Team notes, July 2014 Face-to-Face meeting.

https://serc.carleton.edu/integrate/workspace/july_2014_face-.html [Restricted access]

¹⁰² Program Design> InTeGrate Program Models:

<https://serc.carleton.edu/integrate/programs/implementation/index.html>

“...the development team recognized a tool was needed that was more closely aligned with the expected student outcomes” (p. 140).¹⁰³ In their post-pilot revision, the team supplemented InTeGrate’s two essay questions with three additional CZ-specific essay questions, and replaced the research paper with a team-developed NSF-style proposal for siting a new critical zone observatory.

Difficulties in developing multi-institutional, project-wide assessments

The Assessment Team struggled to develop project-wide assessments that could be used in different institutions, in geoscience courses as well as non-geoscience courses, and in Intro level courses as well as in courses for majors. Discussions on how to thread this needle revealed interesting discordances across U.S. higher education. For example, in the discussion of a metric for student engagement, it emerged that some instructors always took attendance in every class, either for their own purposes or because their institutions required it, while others never took attendance and felt that it would undesirably change the tenor of the class to begin to do so for InTeGrate’s data collection purposes. In the discussion of how to assess systems thinking and interdisciplinary problem solving, it emerged that some courses, especially at the Intro level, almost never gave essay questions and anticipated that students would be resentful and unprepared if suddenly confronted with such questions, while other institutions’ students saw short essay questions routinely at all levels of instruction.

As it turned out, both the GLE and IAI were more sensitive and useful at the Intro level. In courses primarily populated by upper division students or students who were taking the course for their majors, data from both instruments suggests a ceiling effect, where students were already so knowledgeable (GLE) or so environmentally-attuned (IAI) that only limited growth across instruction was possible.¹⁰⁴ Not surprisingly, the quality of essay responses was influenced by students’ mastery of written English language, especially since a high score on the essay rubrics (Exhibit II-22) required being able to express one’s ideas about interactions, causal factors, implications, and relationships, all of which require substantial command of language subtleties.¹⁰⁵

* * * * *

Sub-Claim 1E: Some students who are taught with InTeGrate materials increase in their geoscience literacy, their interest in Earth-related majors and careers, and their ability and motivation to contribute to solving challenges of environmental sustainability and resource limitations.

Geoscience Literacy

The Earth, Ocean, Atmosphere, and Climate Literacy documents were created as a statement of big ideas that need to be grasped by students, the public, and policy makers, in the consensus view of the geoscientists and geoscience educators who contributed to their development.¹⁰⁶ As such, a geoscience educator teaching in college might assume that this knowledge should already be present in incoming

¹⁰³ Dere, A., Englemann, C., White, T., Wymore, A., Hoffman, A., Washburn, J., & Conklin, M. (2019). Implementing and assessing InTeGrate critical zone science materials in an undergraduate geoscience program. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Switzerland: Springer.

¹⁰⁴ Iverson, E., Steer, D., Gilbert, L. A., Kastens, K. A., O’Connell, K., & Manduca, C. A. (2019). Measuring literacy, attitudes, and capacities to solve societal problems. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary teaching about the Earth and environment for a sustainable future*. Switzerland: Springer, pp. 91-119.

¹⁰⁵ Based on evaluator Kastens’ observations as one of the essay scorers.

¹⁰⁶ Geoscience Literacies: https://nagt.org/nagt/teaching_resources/literacies.html (links to the five literacy documents.) The energy literacy document was not yet available when the GLE was developed, so GLE draws from only the ocean, atmosphere, climate, and [solid] Earth literacy documents.

college freshman, covered by K-12 education. Deployment of the GLE-8, GLE-16, and various other individual GLE questions in various contexts throughout the InTeGrate system has conclusively and emphatically shown that this is not the case. For example, Intro-level students taught by the ITG Research Team (n=581) scored, on average, only 11.5 points out of a possible 23 on the GLE-16.¹⁰⁷ Various subsamples of students from pilot enactments of InTeGrate modules averaged only 6.1, 6.3, and 7.0, out of 12 on the pre-instruction GLE-8.¹⁰⁸ The Earth & Space components of the Next Generation Science Standards were influenced by the Geoscience Literacy documents,¹⁰⁹ and it will be interesting to see whether geoliteracy among incoming college students increases in coming years, as the NGSS are adopted and implemented.

The most rigorous study design for analyzing potential gain in geoscience literacy within InTeGrate comes from the Research Team. Czajka (2018)¹¹⁰ analyzed pre- and post-instruction GLE scores of the students of eight instructors during semesters when they did and did not include InTeGrate materials in their intro-level courses. Teaching practices and beliefs were measured for these same instructors (as described above in Section 1C: Shift in Beliefs and Practices of ITG Materials Users). The dosage of InTeGrate materials was 18 units (the equivalent of 3 ITG modules), or 30-40% of the course, and the materials had been piloted, revised and published before the Research Team used them. The Research Team used a 16-item version of the GLE,¹¹¹ as contrasted with the GLE-8 used in the materials development pilots, and used a partial credit technique for scoring the multi-select questions that should improve the reliability and discriminatory power of the items.¹¹² Pre-/post- changes are reported as normalized change scores.¹¹³

Research Team students made significant pre- to post-instruction improvement on the GLE-16 in both the Control and the Treatment semesters. However, there was not a significant difference between normalized change scores for students in the Control versus Treatment semesters, looking across the

¹⁰⁷ Czajka, C.D, unpublished data, and Czajka, C. D. (2018). Chapter 2: Can teaching the geosciences in the context of societal issues have an impact on student geoscience literacy gains? In *Assessing learning and teaching across geoscience courses and curricula*. (PhD dissertation), North Carolina State University, Raleigh, NY. Downloaded from https://repository.lib.ncsu.edu/handle/1840.20/24/browse?rpp=20&offset=40&etal=-1&sort_by=1&type=discipline&value=Marine%2C+Earth+%26+Atmos+Sciences&order=DESC.

¹⁰⁸ Kastens, K.A. & Mara, V. (2016). InTeGrate Evaluation Report: Underrepresented Minorities. Unpublished report downloaded from https://serc.carleton.edu/admin/private_download.php?file_id=93213 [Restricted access]. Mean(SD) pre-instruction GLE-8 for 409 underrepresented minority students: 6.11(1.85). Mean(SD) pre-instruction GLE-8 for 676 white/Asian students: 7.04(1.78).

Caulkins, J. L., Steer, D., Iverson, E., Manduca, C.A., Savina, M.E, and Awad, Aida (2014). Student learning in Geoscience courses incorporating societal issues and grand challenges facing society. *GSA annual meeting abstract* 11-3, https://gsa.confex.com/gsa/2014AM/finalprogram/abstract_248829.htm. Mean(SD) of pre-instruction GLE for 1086 students taught in pilot implementations of InTeGrate modules: 6.3(3.7).

¹⁰⁹ InTeGrate > Prepare Future Teachers > What are the Next Generation Science Standards: https://serc.carleton.edu/integrate/programs/teacherprep/teacherprep_NGSS.html

¹¹⁰ Czajka, C. D. (2018). *Op. cit.*

¹¹¹ Faculty Research Team > GLE: https://serc.carleton.edu/integrate/info_team_members/faculty_research/gle.html (restricted access). Also, Appendix A of Czajka, 2018, *op. cit.*

¹¹² GLE-16 Research Team Level 2 questions were given partial credit by subtracting the probability for incorrect choices from the proportion of correct choices (marked answers and unmarked distractors) make, according to Czajka (2018). GLE-8 studies used a simpler procedure in which Level 2 items received 2 points if all correct answers were selected and 1 point if more answers were correct than incorrect, according to Caulkins et al. (2014).

¹¹³ McKagan, S., E. Sayre, and A. Madsen, (2017). Normalized gain: What is it and when and how should I use it? PhysPort, <https://www.physport.org/recommendations/Entry.cfm?ID=93334>

sample as a whole. Normalized change score for the Control semester was 0.1295 while for the Treatment semester it was 0.1376.¹¹⁴

Two instructors in the Research Team did have significantly better treatment versus control semester outcomes. These same instructors were also ones who had changed their teaching practices towards more student-centered instruction according to RTOP observations.

Among the Research Team students, there were some demographic achievement gaps upon entry: females had significantly lower pre-instruction GLE-16 scores than males, and students identifying their ethnicity as Hispanic had lower pre-instruction GLE-16 scores than non-Hispanics.¹¹⁵ During the Control semester, learning was inequitably distributed, with females achieving less normalized change than males, and Hispanics achieving less normalized change than non-Hispanics (Exhibit II-24). As a consequence, the GLE-16 score gaps between males and females and between non-Hispanics and Hispanics actually widened across instruction during the Control semester. In contrast, during the Treatment semester, the gaps between males and females and between non-Hispanics and Hispanics narrowed across instruction. Czajka connects the stronger normalized change in the Treatment semester to literature showing that collaborative learning has a beneficial effect on female students and active learning has a beneficial effect on underrepresented minorities and first generation students in STEM. However, black students taught by members of the Research Team had the largest entry achievement gap (i.e. lowest pre-instruction GLE-16 scores) of any of the analyzed sub-groups, and their gap was *not* narrowed by InTeGrate-influenced instruction.¹¹⁶

Thus, it seems that some groups of students did increase their geoscience literacy more with InTeGrate-infused instruction than with more traditional, teacher-centered instruction, and the distribution of this learning was preferentially concentrated among some groups of students who, it could be argued, needed it most. However, the post-instruction GLE-16 scores (approximately 13 out of 23 on the GLE-16) still seem to indicate that students are leaving their Intro Geo courses with geoscience literacy substantially below that desired by the writers of the geo literacy documents. Administrations of the GLE-8 instrument elsewhere in the project also show small gains across instruction and incomplete mastery of the Geo literacies at the end of a semester of instruction.¹¹⁷ Earlier researchers had found similarly weak post-instruction mastery of geoscience concepts on a different instrument, the Geoscience Concept Inventory.¹¹⁸

¹¹⁴ Czajka, C.D., unpublished data, email 20 Sept 2018.

¹¹⁵ Czajka, D., unpublished data.

¹¹⁶ Czajka, D., unpublished data.

¹¹⁷ Caulkins, J. L., Steer, D., Iverson, E., Manduca, C.A., Savina, M.E, and Awad, Aida (2014). Student learning in Geoscience courses incorporating societal issues and grand challenges facing society. *GSA annual meeting abstract* 11-3, https://gsa.confex.com/gsa/2014AM/finalprogram/abstract_248829.htm, reports on a sample of 1086 students taught in pilot implementations of InTeGrate modules. Students scored 6.3 +/- 3.7 pre-instruction, and 6.8 +/- 3.8 post-instruction, for a 9% normalized gain, significant at $p < 0.0001$.

Iverson, E., Gilbert, L.A., Steer, D.N., Birnbaum, S.J., and Manduca, C.A. (2016). Assessing student learning about the Earth through the InTeGrate project, *AGU Fall Meeting abstract*, ED11F-03, <https://agu.confex.com/agu/fm16/meetingapp.cgi/Paper/190752>, reports on a sample of 2,023 paired first and last week GLE responses. This group exhibited a 10% normalized gain (equivalent to 1 point gain on the 12-pt GLE-8 exam), with the highest gains occurring in the lowest quartile.

In these cases, the GLE-8 was administered at the beginning and end of the semester in which the InTeGrate instruction was infused. The vast majority of enactments in the first two years of the project were of InTeGrate modules rather than full courses, so that the GLE-8 gains reflect multiple weeks of conventional instruction plus 2-3 weeks of InTeGrate-influenced instruction.

¹¹⁸ Libarkin, J. C., & Anderson, S. W. (2005). Assessment of learning in entry-level Geoscience courses: Results from the Geoscience Concept Inventory. *Journal of Geoscience Education*, 53, pp. 394-401.

Given that most students in an Intro course will take no more college-level Geo courses before graduation,¹¹⁹ this finding calls for some reflection on behalf of the Geo-Ed community: do the literacy documents really represent what geoscience educators think all Americans should know and understand about our planet? And if so, what might be a pathway to achieve that level of knowledge across at least the college-educated populace?

Attitude towards Earth-related majors and careers

Students' attitudes towards Earth-related majors and careers were probed with the InTeGrate Attitudinal Instrument, for a project-wide sample of 3,039 InTeGrate-influenced students. These students were taught by 140 instructors, in 184 enactments, from materials development pilots, IPs, the research team, and assorted other materials testers.¹²⁰ With respect to major and careers:

- On the item that asked, pre- and post-instruction, about respondents' degree of interest in various college majors, there was a small net movement towards Environmental Sciences / Environmental Studies (and a small net movement away from Geosciences) (Exhibit II-25).
- On the item that asked, pre- and post-instruction, about respondents' degree of interest in various professions, there was a substantial decrease in respondents indicating that they don't know enough about the various Earth-related professions to judge. Four professions, those most closely associated with societal issues, showed a net increase of >1% towards "interested" and away from "not interested" or "don't know enough to judge."
- On the item that asked, pre- and post-instruction, how important is it to you to do work in which you use your knowledge of the earth and environment, there was a significant shift towards the "very important" end of the Likert scale.
- On the item that asked, pre- and post-instruction, how important is it to you to work in an organization committed to environmentally sustainable practices, there was again a significant shift towards the "very important" end of the Likert scale.
- When offered a choice of four graphs and asked which most accurately depicts your level of interest in a career in Earth or Environmental Sciences before and after taking this course, one third of students indicated that their level of interest had gone from low before the course to high after the course (Exhibit II-26).

When the sample was subdivided according to respondents' stated reasons for taking the course,¹²¹ the "InTeGrate effect" on respondents' interest in earth-related careers or majors was found to be strongly concentrated among students who indicated that their only reason for taking the course was because of a "General Education or distribution requirement." Students who said they took the course for "Personal Interest," "It counts towards my major," or "I think it will be useful in my career" indicated much less

¹¹⁹ Caryl Edward Buchwald originated the idea that for most students enrolled in an introductory geology course this will actually be their *terminal* geology course in the 1990's. IAI data from the InTeGrate project confirm that this is still the case.

¹²⁰ Further detail in Kastens, K. A., Mara, V., and Turrin, M. (2018). InTeGrate evaluation report: IAI responses spanning the entire InTeGrate project (2012-2016): https://serc.carleton.edu/admin/private_download.php?file_id=162600 [Restricted access]

¹²¹ Kastens, K. A., and Mara, V. (2018). Where is InTeGrate having its impact on Earth and environmental science motivation and action? An analysis of IAI data with respect to student's reason for taking the course. https://serc.carleton.edu/admin/private_download.php?file_id=162600 [Restricted access]

shift in Earth-related career interest across instruction,¹²² at least in part because their initial interest was higher. Within the Gen-Ed-only group, the shift across instruction towards interest in majoring in Environmental Science/Studies was only among women, not among men.

Motivation to tackle Earth-related grand challenges

The same sample of 3,039 IAI respondents was analyzed for attitudes and behaviors that were thought to be indicative of motivation to contribute to solving environmental grand challenges. The following changes were noted across instruction:¹²³

- When offered a choice of four graphs and asked which most accurately depicts their motivation to take action to create a more environmentally sustainable society, 44% of respondents indicated that their level of motivation had gone from low to high.
- On the item that asked, pre- and post-instruction, about level of concern for six potential developments on the Earth (developments that geoscientists would consider to be problematic¹²⁴), there was a significant increase in level of concern across instruction (Exhibit II-27).
- A sustainable behaviors index, constructed by summing the number of environmentally sustainable behaviors the respondent reported engaging in at least once in the prior week, showed a significant increase across instruction.
- When asked, post-instruction, whether they can envision using what they learned in this course to help society overcome problems of environmental degradation, natural resource limitations, or other environmental issues, an overwhelming majority said yes. (However, when invited to expand on their response, many of the answers lacked specificity.)

As with the IAI career questions, the IAI environmental concerns questions also showed a strong split between students who had taken the course only to satisfy a General Education requirement and students who had taken the course for any other reason or combination of reasons (Exhibit 11-27). The GenEd-only group exhibited less environmental concern/interest/behavior pre-instruction and showed more growth across instruction than the other groups.

Attitude towards science

Pelch and McConnell (2018)¹²⁵ researched the impact of InTeGrate curriculum materials on students' attitude towards science and the relevance of science. Prior work had shown that students' attitudes towards sciences often became more negative from the beginning to the end of an undergraduate course.¹²⁶ They hypothesized that teaching about the Earth in the context of issues relevant to students'

¹²² The contrast between the Gen-Ed Only subsample and respondents who checked any other reason for taking the course showed up on the following dimensions probed by the IAI: interest in majoring in Environmental Sciences/Studies, how important respondent thinks it is to do work in which they use their knowledge of Earth and environment, and how important respondent thinks it is to do work in an organization committed to sustainable practices.

¹²³ Kastens, Mara, and Turrin (2018). *Op. cit.*

¹²⁴ Global climate change, population growth, loss of biodiversity, energy resource limitations, water resource limitations, and mineral resource limitations.

¹²⁵ Pelch, M. A., & McConnell, D. A. (2018). How does adding an emphasis on socioscientific issues influence student attitudes about science, its relevance and their interpretations of sustainability? *Journal of Geoscience Education*, 65(2), pp. 203-214.

¹²⁶ Pelch, M. A. (2016). Ch 2: Do our introductory geology courses help students think beyond a class about rocks? Realities of students attitudes toward the nature of science and its relevance after taking a physical geology course. Pelch, M. A., in *Exploring how new teaching materials influence the beliefs and practices of instructors' and students' attitudes about Geoscience*. (PhD), North Carolina State University. And references therein.

lives, such as the societal issues embedded in the InTeGrate curriculum materials, could improve students' attitude towards science. This, in turn, could be valuable in attracting and retaining students in the STEM pipeline.

Pelch taught an introductory Physical Geology course for two semesters using the established curriculum materials (the Control semesters), followed by two semesters in which 4 InTeGrate modules substituted for about 60% of the curriculum (the Treatment semesters). Class sizes ranged from 70 to 87. In all four semesters, students were given the revised Scientific Attitude Inventory (SAI II) pre- and post-instruction, the Change in Attitude about the Relevance of Science (CARS) survey 3 times during the semester, plus a project-developed short answer assessment of their ability to define and discuss sustainability on the final exam.¹²⁷ Results did not show strong control/treatment contrasts in the desired direction (Exhibit II-28). Students did show an increase in CARS scores across both Treatment semesters—but they also did so on one of the Control semesters. On the SAI II, attitude towards science got statistically worse across instruction in the Control semesters and the first Treatment semester, and showed no change on the second Treatment semester. The sustainability responses from the final exam were coded for two emergent themes: Sustainability (Future) in which respondents explicitly describe the importance of conserving resources for future generations, and Sustainability (Balance), in which respondents explicitly describe the balance between humanity and natural systems. The percent of coded statements referencing either of these themes was low in all semesters, and did not show improvement from Control to Treatment.

An interesting aspect of this study is that the instructor was also observed with RTOP three times per semester during both control and treatment semesters, with the treatment observations occurring during non-ITG class sessions. RTOP scores were high (52-55, firmly in the student-centered domain) in all four semesters. The promise of InTeGrate's instructional materials is two-fold: to encourage and support more student-centered pedagogy and to enable teaching in the context of compelling societal issues. In most InTeGrate studies and enactments, it is impossible to disentangle the beneficial effects, if there are such effects, of these two changes. In this study, however, instruction was already quite student-centered before the intervention began, and so these findings can be viewed as a test of the impact on student attitudes of changing only the content focus.

Ability to tackle Earth-related grand challenges: Systems thinking and interdisciplinary problem solving

A broad range of skills, knowledge, understanding, and habits of mind are required to contribute to solving challenges of environmental sustainability and resource limitations. For the InTeGrate evaluation, the evaluation team chose to focus on two constructs: *systems thinking*, and *interdisciplinary problem solving*. These two constructs were chosen early in the evolution of InTeGrate because: (a) they are applicable to a wide range of problems at the intersection between human and natural systems, (b) teaching them was thought to be doable (although challenging), and (c) assessing them was thought to be doable (although challenging). Development of the essay assessments for these two constructs is described above, in Section 1D.

Gilbert et al (2017; in prep),¹²⁸ have analyzed the systems thinking essay responses, comparing the performance of a group who studied geoscience without InTeGrate materials and a group who took a

¹²⁷ For SAI II, see <http://stellar.edc.org/instruments/scientific-attitudes-inventory-ii-sai-ii>. For CARS, see <http://www.pearweb.org/atis/tools/27>. Sustainability assessment prompts: (1) define sustainability in the geosciences, (2) identify topics that deal with sustainability, and (3) describe why one of those topics would be important to know to be scientifically literate.

¹²⁸ Gilbert, L. A., Iverson, E., Kastens, K., Awad, A., McCauley, E. Q., Caulkins, J. L., . . . Manduca, C. A. (2017). Explicit focus on systems thinking in InTeGrate materials yields improved student performance. *Geological Society of America Abstracts with Program*, 49(6). doi: 10.1130/abs/2017AM-304783. Gilbert, Lisa A., Iverson, E., Kastens, K.A., and Manduca, C.A. Improving Systems Thinking in U.S. Undergraduates, in prep for *Science* magazine.

course that incorporated at least one module (2-3 weeks) of InTeGrate materials. The groups were matched for demographics and for performance on the test of geoscience literacy (GLE). Because performance on a systems thinking task depends in part on knowledge about the system, and because performance on an essay assessment depends in part on writing ability, a model was created that relates InTeGrate students' geoscience literacy score to their essay score on a non-systems geoscience essay question (the interdisciplinary problem solving task). Students whose systems essay was more than 1.2 root mean squared errors better than would have been predicted by their non-systems essay and GLE score were considered "very strong" in systems thinking, while those whose systems essay scores were more than 1.2 RMSE worse than predicted were considered "very weak" in systems thinking (Exhibit II-29); those in between were designated as "proportional" to their geoscience literacy. Of the InTeGrate group, 65% exhibited systems thinking in proportion to their geoscience literacy, and 8% exhibited very strong systems thinking. In contrast, only 11% of the control group exhibited systems thinking proportionate to their geoscience literacy, and none exhibited very strong systems thinking. Thus, Gilbert et al. concluded that students instructed with InTeGrate materials have ended their courses with stronger systems thinking skills than those taught without InTeGrate materials.

Unfortunately, there is no comparable analysis of project-wide data from the Interdisciplinary Problem Solving essay. Although these essays were used formatively by the materials development teams, the person working on the project-wide analysis of this data was unable to complete the task in time for this report. Early results (project year 3) contrasting students in courses where an InTeGrate intro-level module was being piloted, versus a control section without InTeGrate, showed an intriguing pattern in which the non-ITG students were most likely to focus on global climate change as the grand challenge while the ITG students were more likely to focus on the topic of their ITG module. From this comparison, the authors inferred that InTeGrate had successfully broadened the scope of student understanding to include non-global-warming environmental challenge(s).¹²⁹ However, this inference remains tentative, in that the essay data are post-instruction only.

Known weaknesses in the InTeGrate essay data are (a) that most data were collected during the pilot-testing phase for the instructional materials, and one might expect that student outcomes would be stronger on the revised materials, and (b) the essay questions were only given post-instruction.¹³⁰ A few development teams, of their own volition, collected data in ways that overcame one or both of these issues. Of particular note is data from the Critical Zone Science course reported by Dere et al. (2019),¹³¹ who collected data at the same university on both essay questions both pre- and post-instruction, on the pilot test enactment and on a post-revision enactment (Exhibit II-30). These data show pre-/post-improvement on both essay questions, with more improvement on the post-revision (2017) enactment than the pilot test enactment (2015). This sample size is small (n=12), but gives a glimpse of the kind of data that would have been needed to gauge the full student learning gains of the post-revision versions of the instructional materials.

¹²⁹ Caulkins, J. L., Steer, D., Iverson, E., Manduca, C., Savina, M. E., & Awad, A. (2014). Student learning in Geoscience courses incorporating societal issues and grand challenges facing society. *Geological Society of America Abstracts with Program* (11-3).

¹³⁰ There were practical reasons for these decisions. The commitment being asked of development teams was already quite long and ambitious, and the publication of a revised set of curriculum materials represented a clear goal and natural stopping point for the teams. The essay questions were thought to be too difficult and potentially confusing to offer pre-instruction, especially in the Intro level courses. The Critical Zone development team were teaching at the upper division level, and so the essay questions could tap into knowledge from previous college level Earth and environmental courses.

¹³¹ Dere, A., Englemann, C., White, T., Wymore, A., Hoffman, A., Washburn, J., & Conklin, M. (2019). Implementing and assessing InTeGrate critical zone science materials in an undergraduate geoscience program. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Switzerland: Springer.

Under-represented minorities

Like most STEM disciplines, Geosciences has relatively few individuals in the workforce and educational pipeline among the groups known as “Under-represented minorities” or “URM’s.”¹³² Only 34 underrepresented minorities graduated in 2014 with doctorates in Earth, atmosphere or ocean sciences, and this number has barely budged over the last 40 years.¹³³ Therefore, it is of interest to compare the effectiveness of InTeGrate materials with URM’s versus non-URM’s as a gauge of whether InTeGrate may be helping to solve this pipeline problem.

The InTeGrate Attitudinal Instrument (IAI) survey asks respondents to identify their ethnicity (Hispanic, non-Hispanic or prefer not to answer) and race (Alaskan Native, American Indian, Asian, Black, Pacific Islander, White and/or Prefer not to answer). These items were asked on the pre-instruction survey only, and were positioned at the end of the survey so as to avoid the risk of stereotype threat. For race, the respondent could select more than one option. Based on these responses, students were categorized as URM (under-represented minorities) if they checked Hispanic, or Alaska Native, or American Indian, or Black, or Pacific Islander.

The IAI responses of URM and non-URM respondents were compared for 1125 students who participated in pilot tests of InTeGrate materials between Fall of 2012 and Summer of 2015.¹³⁴ In many aspects of their interest in Earth-related careers, and their attitudes and behaviors around environmental sustainability, the underrepresented minorities who responded to the InTeGrate Attitudinal Instrument survey equaled or exceeded their non-URM peers. The measures on which URM’s outpaced non-URM’s were: “importance placed [post-instruction] on doing work in which you use your knowledge of the earth and environment” (Exhibit II-31, upper); fraction of respondents who indicated graphically that their interest in a career in Earth or Environmental Science had increased across instruction (Exhibit II-31, lower); Environmental Concern Index (pre- and post- instruction); fraction of the sample who indicated graphically that their degree of motivation to take action to create a more environmentally sustainable society had increased across instruction; and fraction who could envision themselves using what they had learned in this course to help society overcome sustainability challenges by taking action in their personal lives. On the other hand, URM’s reported engaging in fewer sustainability activities in the last week than non-URM’s, and although both groups gained significantly across instruction on this measure, this URM/non-URM gap did not close.

Results from the GLE-16 and GLE-8 show that, on average, females and students from groups historically underrepresented in science began instruction with lower levels of geoscience literacy than males and non-URM students. There is some evidence that non-InTeGrate instruction may exacerbate achievement gaps in geoscience literacy between females/males and between Hispanics/non-Hispanics, while InTeGrate-infused instruction contributes to filling those gaps (Exhibit II-24.)

Some of the Implementation Programs (see Claim 2) with a focus on inclusion and broadening participation also collected relevant data on student learning outcomes and attitudes among underrepresented minorities. Doser and Hussein (2019)¹³⁵ present six years’ of data from an upper level

¹³² NSF classifies Hispanics or Latinos, blacks or African Americans, and American Indians or Native Americans, as underrepresented minorities.

¹³³ National Science Foundation (2017). Women, minorities, and persons with disabilities in science and engineering: 2017 NSF 17-310. Bernard, R. E., & Cooperdock, E. H. G. (2018). No progress on diversity in 40 years. *Nature Geoscience*, 11, pp. 292-295.

¹³⁴ Kastens, K., & Mara, V. (2016). InTeGrate Evaluation Report: Underrepresented Minorities. Online at: https://serc.carleton.edu/admin/private_download.php?file_id=93213 [Restricted access]

¹³⁵ Doser, D., & Hussein, M. J. (2019). Implementing InTeGrate materials in an upper division undergraduate engineering course In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 257-276.

Geology for Engineers course: two years prior to the introduction of ITG materials, followed by four years in which ITG content comprised 33-40% of the course. More than 80% of the students in all years were Hispanic. They found a step upward in mean course grade after the incorporation of the InTeGrate material. Students' responses to a question of "Which in-class activity did you like best and why?" suggest that the connections to societal issues were indeed engaging for these students:

- *I liked the activity where we had to compare two articles about phosphorous... it showed the two sides of a problem and it made you analyze it.*
- *... dealing with economic factors of food, land resources and cost. Most impoverished countries had a low GDP but high demand due to population.*
- *I liked the aquifer activity. I liked it because water purification methods are a big attraction in El Paso and this activity gave me more insight into the problem of water usage and the need to replenish what is taken from the ground.*

Under the leadership of Richard D. Schulerbrandt Gragg III, InTeGrate's Historically Black Colleges and Universities (HBCU) Working Group has recruited a cohort of HBCU instructors¹³⁶ to test InTeGrate materials in their classrooms, to better understand the impact of InTeGrate materials and the underpinning design principles on student attitudes and learning. As of July, 2018, student data had been received from 13 enactments, spanning 11 instructors at 5 institutions.¹³⁷ Data analysis will continue into 2019, as building education research capacity is one of the goals of the HBCU Working Group.

* * * * *

Status of Evidence for Claim 1

The evidence is strong that InTeGrate created an effective and scalable (albeit labor-intensive) system for collaborative development of undergraduate instructional materials, and that the resulting materials covered a wide range of environmental grand challenges, and involved students in addressing societal issues while using systems thinking, interdisciplinary problem solving, and geoscience habits of mind. The resulting materials have proven to be adaptable to a variety of institutional and instructional contexts and educative for the faculty who use them, and they have been widely adapted and adopted. From our current perspective, seven years into the project with a suite of tested and polished modules and courses on the website, it is possible to forget or under-estimate how big a lift was involved in spinning up this materials development system. Colleagues who are contemplating starting a similar materials development effort would be well-advised to review the experiences of the early cohorts as documented in the mid-project report,¹³⁸ where they will read of a multitude of problems overcome and lessons learned.

There is also very strong evidence, from interviews, several different surveys, written reflections, instructor stories, published papers and presentations, and classroom observations, that faculty members who participated in the InTeGrate materials development process found it to be a powerful professional development opportunity. They changed both their beliefs and teaching practices, in ways that appear to be lasting and to have spread beyond the specific course or module they developed during their InTeGrate sub-award. For faculty members with a less intensive InTeGrate professional development experience,

¹³⁶ HBCU Research Team website:
https://serc.carleton.edu/integrate/info_team_members/hbcu_testers_team/index.html

¹³⁷ from InTeGrate Course Overview webpage:
https://serc.carleton.edu/admin/assess/course_overview.php?project_module_id=2244 [Restricted access]

¹³⁸ Kastens, Baldassari & DeLisi (2014). *op. cit.*

the evidence is mixed, as would be expected from their varied circumstances and level of InTeGrate engagement. Interviews and instructor stories convey that some non-developer instructors were substantially impacted, reporting changes to their teaching strategies and/or content focus. Quantitative data from the Research Team likewise show some instructors with substantial shifts in teaching beliefs and reformed teaching practice from their pre-ITG semester to their with-ITG semester.

With respect to assessment, InTeGrate did succeed in developing a functional system for distributed assessment of student learning, and this system did collect data used both formatively for program improvement and summatively for program evaluation. Several other projects are now using aspects of InTeGrate's data collection/scoring/archiving system,¹³⁹ including GEodsy Tools for Societal Issues (GETSI), the Quantitative Literacy and Reasoning Assessment (QLRA), Environmental Data-Driven Inquiry and Exploration (EDDIE), and the Liberal Arts Consortium for Online Learning Project (LACOL). One important lesson learned has been just how challenging it is to collect and combine data from higher-education classrooms and from instructors across the country, a lesson that will be important as the Geoscience Education Research community tries to push towards multi-institutional studies.¹⁴⁰

The summative and embedded assessments developed as part of InTeGrate modules and courses continue to be used along with the materials. On the other hand, the project wide assessments (GLE, IAI, systems and interdisciplinary essay prompts) have not been adopted by projects outside of InTeGrate, to the best of our knowledge. These assessments all have data from a diverse and nationwide sample. It was a sample of opportunity, rather than a more ideal random or purposefully-designed sample. But it is, nonetheless, a meaningful comparison group against which the leaders of future intervention projects may want to compare their own students. The 5-year planned timeline of InTeGrate and the lack of existing instruments resulted in InTeGrate deploying instruments that had not gone through as extensive a cycle of develop/test/refine/validate/deploy as an assessment professional would have liked. If they are to be re-used, an additional round of testing and refinement might be warranted--but then one would lose the advantages of a national comparison group.

The project-wide evidence of student growth in desired directions is weaker than the evidence for faculty. InTeGrate-instructed students do increase their Geoscience Literacy as measured by the GLE, but not significantly more than conventionally-instructed geoscience students. With respect to attitude to science and relevance of science, a Physical Geology course infused with InTeGrate materials did no harm, as contrasted with an InTeGrate-free course taught to similar students by the same instructor, which, like many other Intro-level college courses, resulted in a *worsening* in students' attitude toward science. InTeGrate-influenced students show increases across instruction on IAI items probing their interest in environmental majors and Earth-related professions, their concern and motivation about Earth-related issues, and their exercise of sustainability behaviors. The shifts are small, and are concentrated almost entirely among students taking the course to satisfy a gen ed or distribution requirement. One bright spot in the student data is the evidence of increasing mastery of systems thinking among InTeGrate students. Systems thinking is essential for tackling many environmental grand challenges and yet is difficult to teach. Another promising development is that instruction with InTeGrate materials may be closing some pre-existing gaps in geoscience literacy among women and under-represented minorities

¹³⁹ GETSI: <https://serc.carleton.edu/getsi/index.html>. QLRA: <https://serc.carleton.edu/qlra/index.html>. EDDIE: <https://serc.carleton.edu/eddie/index.html>. LACOL Q-bits Portal: <https://serc.carleton.edu/qbits/index.html>. The identification of these projects as using parts of the data collection/scoring/archiving system developed by InTeGrate is by Cathy Manduca, September 2018, at the Evaluation meeting, Carleton.

¹⁴⁰ The need for the field of Geoscience Education Research to move beyond single-course studies and move towards multi-institutional studies was articulated at the 2015 Workshop on Synthesizing Geoscience Education Research: Where are We? What is the path forward at the 2015 Earth Educators Rendezvous: (https://d320goqmyal8dw8.cloudfront.net/files/earth_rendezvous/2015/morning_workshops/w3/first_steps_toward_synthesizing.pdf) and then re-affirmed at the GER workshops at the 2016 and 2017 Rendezvous.

(URM) and increasing motivation among URM's towards careers involving the Earth and environment. Finally, the embedded assessments included in the ITG instructional materials challenged students to demonstrate their understanding of Earth processes by exercising practices of science such as analyzing and interpreting data, engaging in argumentation from evidence, and communicating with varied audiences including community stakeholders. As these embedded assessments were idiosyncratic to each module, they cannot be summed across the project to yield a project-wide measure of student learning, but they do hold promise that in classes across the country, educators will be able to detect whether their students are constructing deep understanding of Earth processes.

Exhibit II-1: A simplified model of how the sub-claims within Claim 1 fit together into a system that can improve teaching and learning about the Earth among faculty and students influenced by InTeGrate. An orchestrated collaborative development process (1A) leads to better instructional materials (1B), which leads to better instructional practices (1C), which leads to improved student learning (1E), as attested by a system of student assessment (1D). A few additional synergies and influences are shown; many others are discussed in the text.

Connections among sub-claims about InTeGrate's improvement of Earth education.

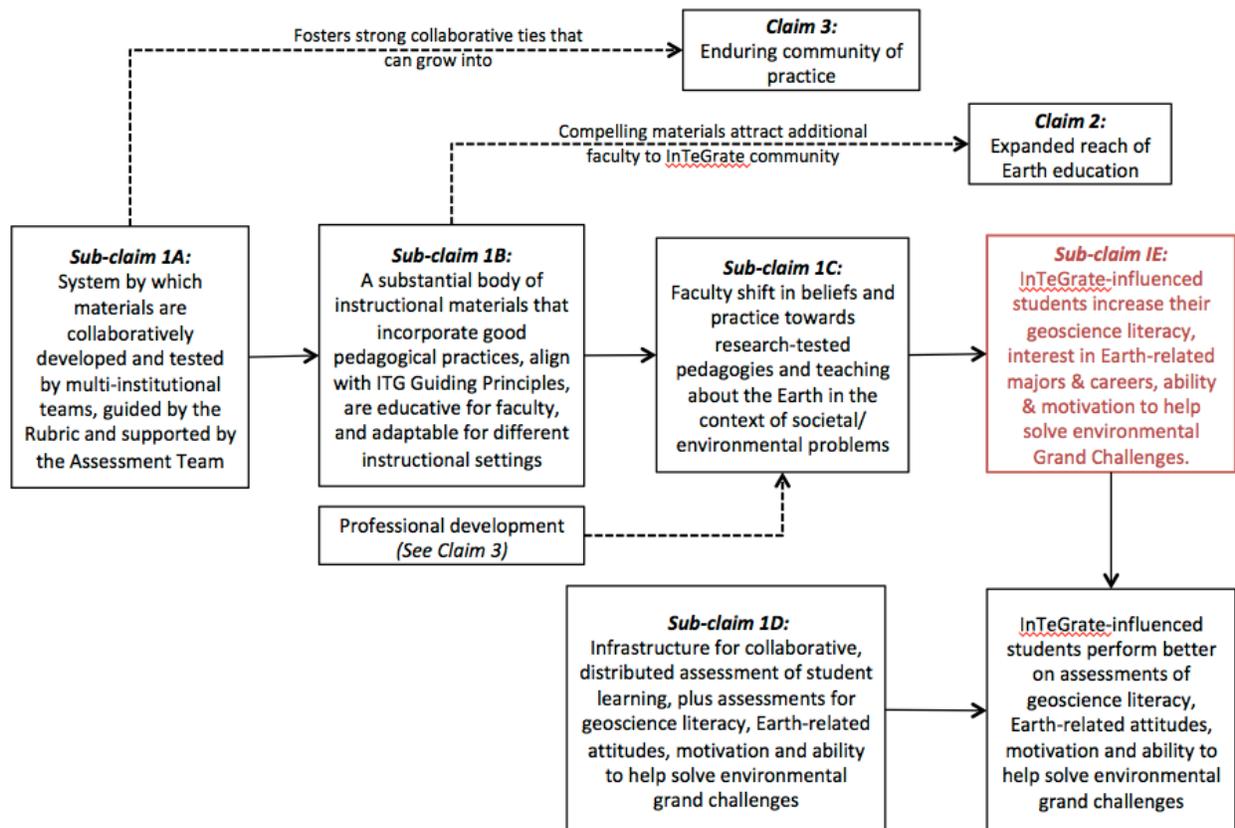


Exhibit II-2: InTeGrate's Curriculum Development & Refinement Rubric was used to communicate InTeGrate's values and priorities to materials developers, to gauge materials' progress towards ready-to-pilot, and to refine the professional development program for materials developers. From Steer, et al (2019). Future elaboration at <https://serc.carleton.edu/71079>.

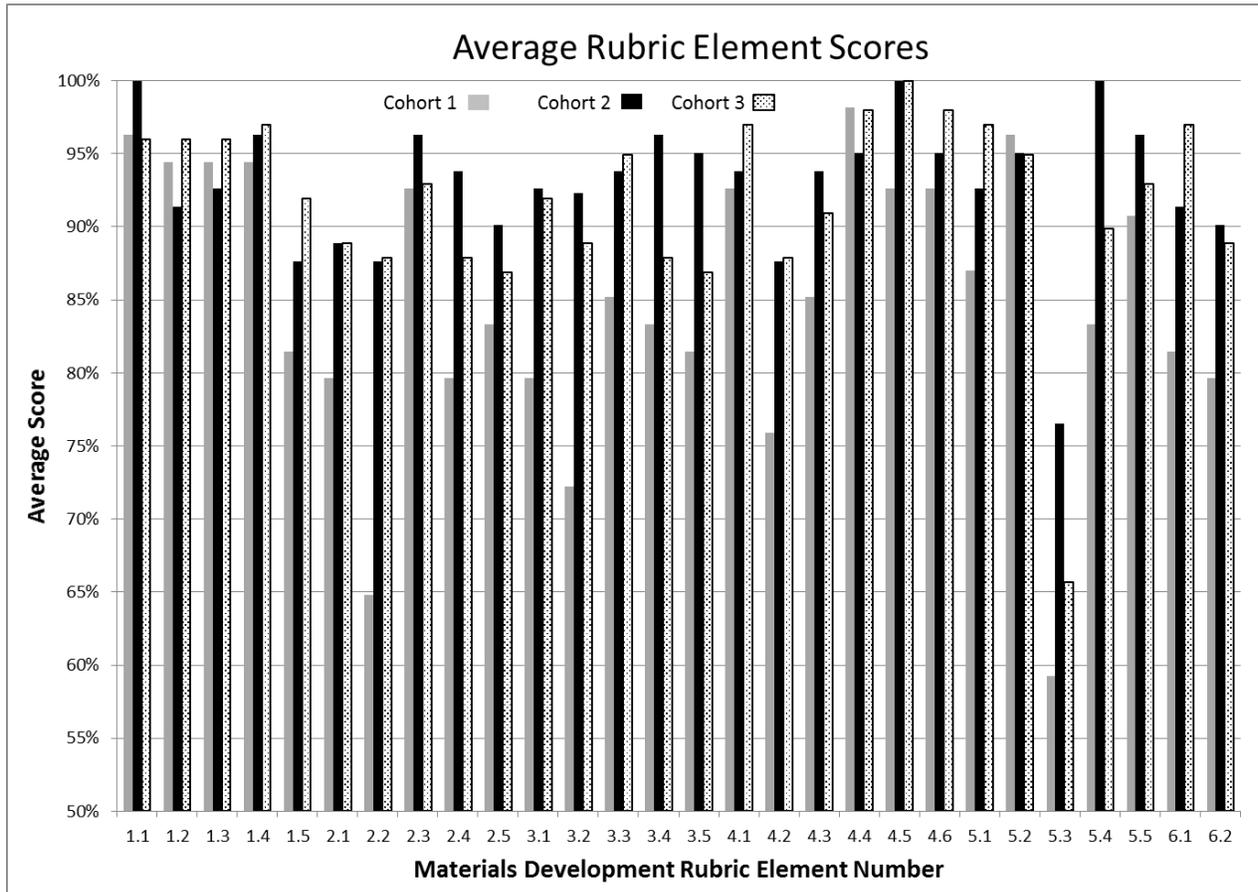
Table 1: InTeGrate Curriculum Development and Refinement Rubric

<p>This rubric is designed to guide InTeGrate assessment team members as they score modules and courses to improve geoscience literacy. The evaluation scheme is divided into six sub-areas: overarching goals, learning objectives and outcomes, assessment and measurement, resources and materials, instructional strategies, and alignment. The six sub-areas have a total of 28 elements that are equally weighted at 3 points each and are evaluated using the following scoring scheme:</p> <ul style="list-style-type: none"> • 3 points: rubric element explicitly and/or pervasively addressed in module/course materials • 2 points: rubric element addressed in majority of the module/course materials • 1 points: rubric element addressed in some of the module/course materials • 0 points: rubric element not addressed in the module/course materials <p>A score of 15/15 must be achieved on the Overarching goals portion of the rubric. Scores of 85% or higher must be achieved in each of the other sub-areas of the materials rubric. Materials meeting the above criteria will earn a minimum score of 74/84.</p>		
1. Overarching goals (Must score 15/15)	Points	Score
1.1 Course/module addresses one or more geoscience-related grand challenges facing society	3	
1.2 Course/module develops student ability to address interdisciplinary problems	3	
1.3 Course/module improves student understanding of the nature and methods of geoscience and developing geoscientific habits of mind	3	
1.4 Course/module makes use of authentic and credible geoscience data to learn central concepts in the context of geoscience methods of inquiry	3	
1.5 Course/module incorporates systems thinking	3	
2. Learning objectives (Must score 13/15)		
2.1 Learning objectives describe measureable geoscience literacy outcomes	3	
2.2 Instructions and/or rubrics provide guidance for how students meet learning outcomes	3	
2.3 Learning objectives and outcomes are appropriate for the intended use of the course/module	3	
2.4 Learning objectives and outcomes are clearly stated for each module in language suitable for the level of the students	3	
2.5 Learning objectives and outcomes address the process and nature of science and development of scientific habits of mind	3	
3. Assessment and Measurement (Must score 13/15)		
3.1 Assessments measure the learning objectives	3	
3.2 Assessments are criterion referenced	3	
3.3 Assessments are consistent with course activities and resources expected	3	
3.4 Assessments are sequenced, varied and appropriate to the content	3	
3.5 Assessments address outcomes at successively higher cognitive levels	3	
4. Resources and Materials (Must score 15/18)		
4.1 Instructional materials contribute to the stated learning objectives	3	
4.2 Students will recognize the link between the learning objectives, outcomes and the learning materials	3	
4.3 Instructional materials should be sufficiently diverse and at the depth necessary for students to achieve learning objectives and outcomes	3	
4.4 Materials are appropriately cited	3	
4.5 Instructional materials are current	3	
4.6 Instructional materials and the technology to support these materials are clearly stated	3	
5. Instructional Strategies (Must score 13/15)		
5.1 Learning strategies and activities support stated learning objectives and outcomes	3	
5.2 Learning strategies and activities promote student engagement with the materials	3	
5.3 Learning activities develop student metacognition	3	
5.4 Learning strategies and activities provide opportunities for students to practice communicating geoscience	3	
5.5 Learning strategies and activities scaffold learning	3	
6. Alignment (Must score 5/6)		
6.1 Teaching materials, assessments, resources and learning activities align with one another	3	
6.2 All aspects of the module/course are aligned	3	
Total	84	

Exhibit II-3: Materials were developed by 3-7 person, multi-institutional, interdisciplinary teams; “x” indicates that at least one faculty member of that discipline was on the development team for that module. (from Egger, et al, 2019).

Modules	Level	Geo-scientist(s)	Other scientist(s)	Non-scientist(s)
Climate of Change	introductory	x	-	-
Natural Hazards and Risks: Hurricanes	introductory	x	-	-
Human's Dependence on Earth's Mineral Resources	introductory	x	-	-
A Growing Concern: Sustaining Soil Resources Through Local Decision Making	introductory	x	x	-
Map Your Hazards! Assessing Hazards, Vulnerability and Risk	introductory	x	-	x
Living on the Edge	introductory	x	-	-
Environmental Justice and Freshwater Resources	introductory	x	-	-
Carbon, Climate, and Energy Resources	introductory	x	-	-
Systems Thinking	introductory	x	x	-
Earth's Thermostat	introductory	x	x	-
Ocean Sustainability	introductory	x	x	-
The Wicked Problem of Global Food Security	introductory	x	x	x
Changing Biosphere	introductory	x	x	-
Exploring Geoscience Methods	pre-service teach.	x	-	-
Interactions between Water, Earth's Surface and Human Activity	pre-service teach.	x	-	-
Soils, Systems, and Society	pre-service teach.	x	x	x
Cli-Fi: Climate Science in Literary Texts	intro-intermed.	x	-	x
Mapping the Environment with Sensory Perception	intro-intermed.	x	-	x
An Ecosystem Services Approach to Water Resources	intro-intermed.	x	x	x
Water, Agriculture, and Sustainability	intro-intermed.	x	-	-
Food as the Foundation for Healthy Communities	intro-intermed.	x	x	x
Regulating Carbon Emissions	intro-intermed.	x	-	x
Major Storms and Community Resilience	intro-intermed.	x	x	x
Environmental Justice and Freshwater Resources - Spanish Version	intro-intermed.	x	-	x
Lead in the Environment	intermed.-adv.	x	x	-
Water Sustainability in Cities	advanced	x	x	-
Courses				
Coastal Processes, Hazards, and Society	introductory	x	-	-
Water: Science and Society	introductory	x	-	-
Future of Food	introductory	x	x	-
Renewable Energy and Environmental Sustainability	intro-intermed.	x	x	-
Critical Zone Science	intermed.-adv.	x	x	-
Modeling Earth Systems	intermed.-adv.	x	-	-
	TOTALS	32	15	10

Exhibit II-4: Evolution of the average rubric scores from Cohort 1 (teams formed in 2012, project year 1), to Cohort 2 (2013-2014), to Cohort 3 (2015-2016). Materials development rubric element number is keyed to Exhibit II-2. Of the required elements, Systems thinking (1.5), caused the most failures in Cohort 1, and was subsequently improved through enhanced professional for materials developers. Metacognition (5.3) remained the most challenging element throughout the three Cohorts. (from Steer et al, 2019).



<i>Exhibit II-5</i>		
Individuals with authorship roles in both InTeGrate and GETSI		
Name & Affiliation	InTeGrate authorship role	GETSI authorship role
Becca Walker, Mt. San Antonio College	Co-developer of <i>Climate of Change</i>	Co-developer of <i>Surface Process Hazards; Ice Mass & Sealevel Change; Water Hazards & resources</i> (in development)
Philip Resor, Wesleyan University	Co-developer of <i>Earth's Thermostat</i>	Co-developer of <i>GPS, Strain, and Earthquakes</i>
Rachel Teasdale, Cal State Chico	Co-developer of <i>Living on the Edge</i>	Co-developer of <i>Volcanic Hazards</i> (in development)
GETSI authors without prior InTeGrate authorship role: Sarah Hall, Leigh Stearns, Bruce Douglas, Kate Shervais, Chris Crosby, Gareth Funning, Vince Cronin, Benjamin Crosby, Ian Lauer, Kaatje Kraft, Karen Kortz, Jessica Smay, Jonathan Harvey, Stephen Hughes, Bobak Karimi, James McNamara, and Susan Kaspari.		

Exhibit II-6: Tallies of how many InTeGrate courses and modules address critical needs for geosciences as defined by AGI (2016). Some materials addressed more than one critical need. Figure from Egger, Bruckner, Birnbaum & Gilbert (2019).

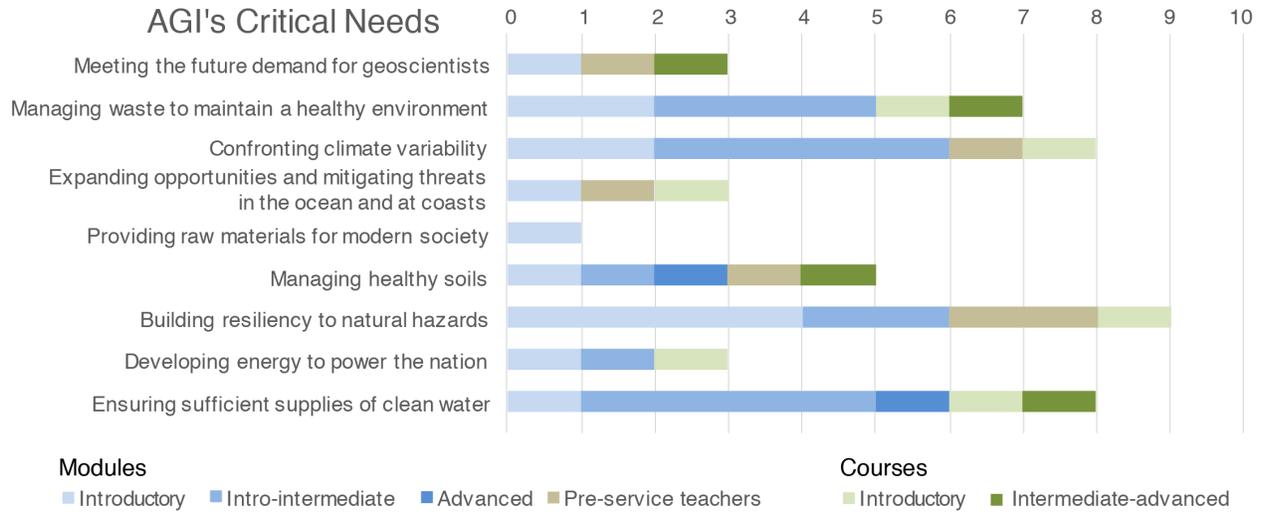


Exhibit II-7: Tallies of how many InTeGrate materials address each of the NGSS’s Disciplinary Core Ideas (Upper), Science & Engineering Practices (Middle), and Cross-cutting Concepts (Lower). (from Egger, Fox, McDaris & Gilbert, 2017)

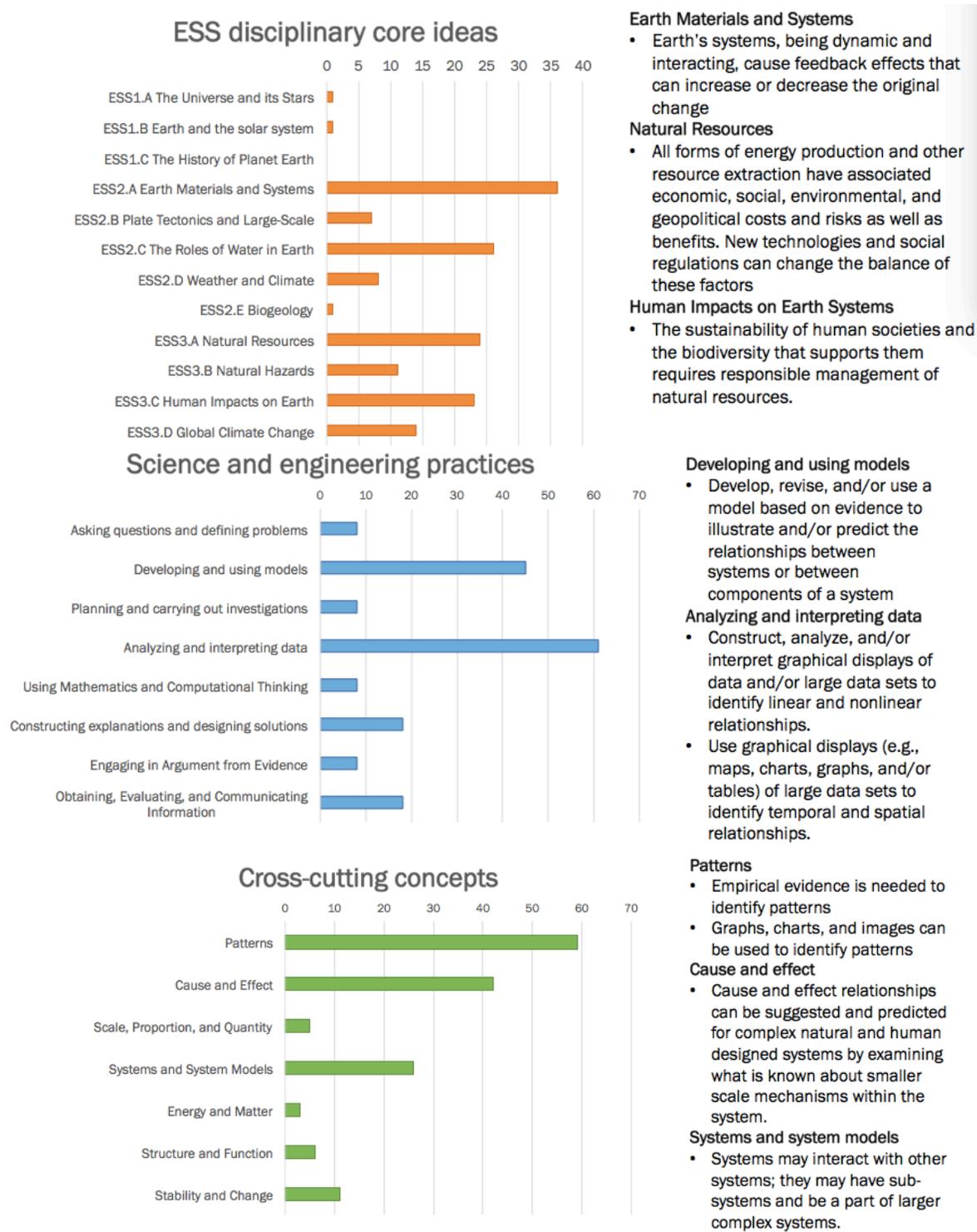


Exhibit II-8: Synthesis of instructional strategies that InTeGrate developers used to engage students in the use of authentic, credible geoscience data, as required by Guiding Principle #4. From Kastens & Krumhansl (2017)

<i>Instruct. Strategy (aka Design Pattern)</i>	<i>Key Characteristics</i>	<i># of Instances</i>
Data Puzzle	<ul style="list-style-type: none"> • Snippets of high insight:effort ratio data preselected by curriculum designer • Data moves that require observation and description of data (e.g., describe patterns/relationships/trends; compare and contrast data) • Data moves that require interpretation of data (e.g., develop potential explanation for pattern/relationship/trend; consider the consequences for humans of phenomenon shown in the data) • <i>Culmination:</i> Students experience an “Aha!” as they interpret concrete data in terms of processes learned in the abstract 	22
Pooling Data to See the Big Picture	<ul style="list-style-type: none"> • Individually or in groups, students interpret different datasets pertaining to the same phenomenon. • Compare and contrast data. • <i>Culmination:</i> Combine insights from multiple data sources to make an inference, see a pattern, or explain a phenomenon. 	8
Make a Decision or Recommendation	<ul style="list-style-type: none"> • Data moves that require observation, description, and/or interpretation of data • Scenario about a situation that requires a decision about a human action to be taken in regard to Earth/human interaction. • <i>Culmination:</i> Make a decision or recommendation grounded in data; explain and defend the reasoning behind the decision. 	8
Predict-Observe-Explain	<ul style="list-style-type: none"> • Gain familiarity with a system through data and/or models. • Make a prediction of how data will look under not-yet-observed conditions. • Explain the reasoning behind your prediction • Propose how to test the prediction with further data • <i>Culmination:</i> Test prediction with data. Compare and contrast predicted behavior with data; discuss agreements and discrepancies. 	5
Nested Data Sets	<ul style="list-style-type: none"> • Students interpret a local data set, drawing on local knowledge and personal observations • Students access data covering a larger area, longer time span, or larger populations • Describe patterns/relationships/trends in larger dataset • <i>Culmination:</i> Leveraging experience with local data, interpret larger data set to make an inference, see a pattern, or explain a phenomenon. 	3
Deriving a New Data Type	<ul style="list-style-type: none"> • Perform a series of calculations based on data • Convert units to develop a derived data type • <i>Culmination:</i> Leveraging insights into how the new data type was derived, interpret a data set of the derived data type to make an inference, see a pattern or explain a phenomenon 	3

Exhibit II-9: Each bar represents one of the 32 InTeGrate courses or modules. The height of the bar shows the number of times an enactment reporting use that course or module appears in the InTeGrate database of classroom usages. Red bars are Intro-level, and black bars are non-Intro (including Intro-Intermediate, see Exhibit II-3.) The uptake of InTeGrate materials varies widely across the portfolio. The highest uptake was among Intro modules.

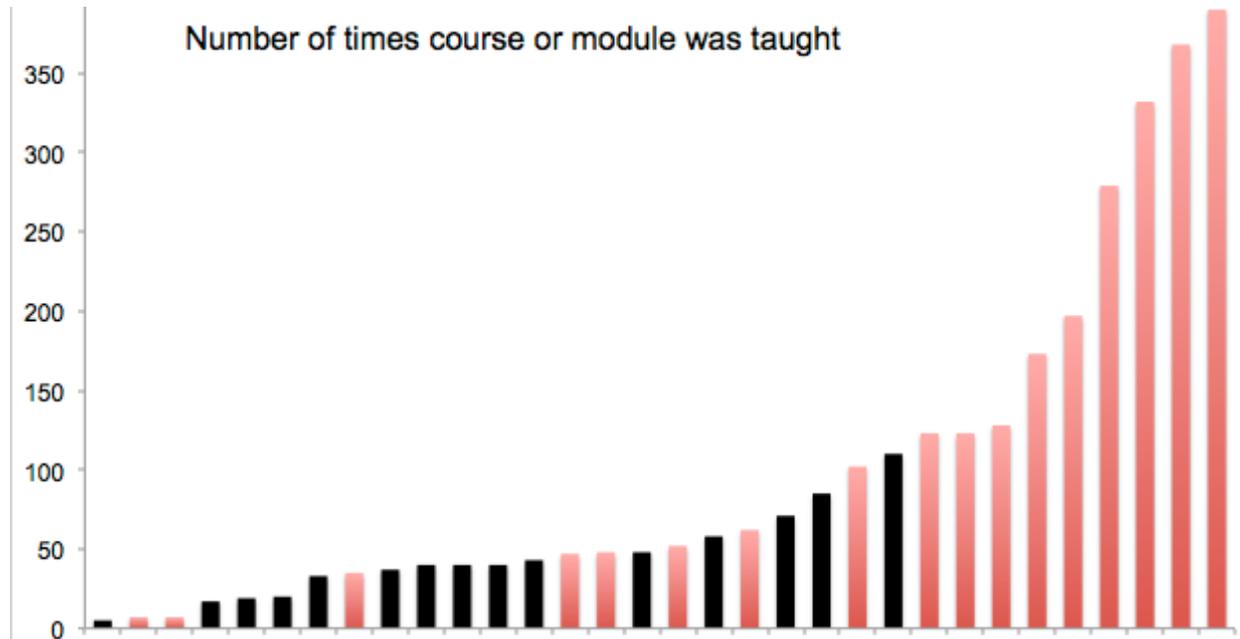


Exhibit II-10: The 110 faculty members who worked on curriculum materials development in the InTeGrate project represented a wide range of institution types and geographic regions. *(Right)* Institution types of authors, based on a modified Carnegie classification scheme. *(Below)* Geographic distribution of authors. Data and figures from Egger et al. (2019).

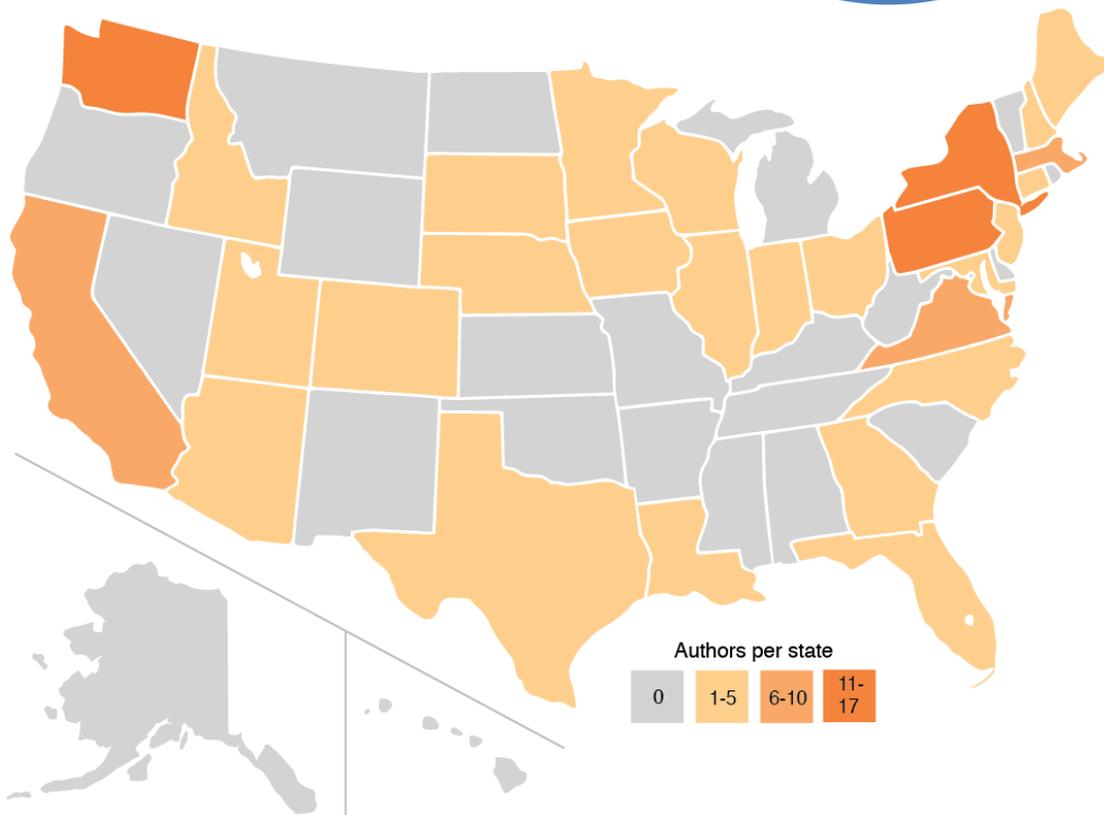
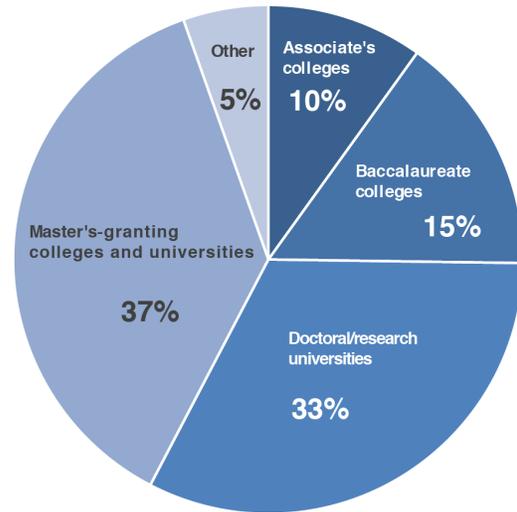


Exhibit II-11: Results from of the Teaching Beliefs Interview (TBI) on 21 developers of Introductory-level InTeGrate modules, at the beginning and end of the development process. Figures from Pelch & McConnell (2016). (Upper) Pre- and post- TBI scores for individuals. Names are pseudonyms. Scores are out of a possible maximum of 35; larger numbers indicate more reform-based responses and smaller numbers are more traditional. (Lower) TBI data by interview question. Questions in the left column show little change from pre- to post-surveys, while questions in the right column show more significant change.

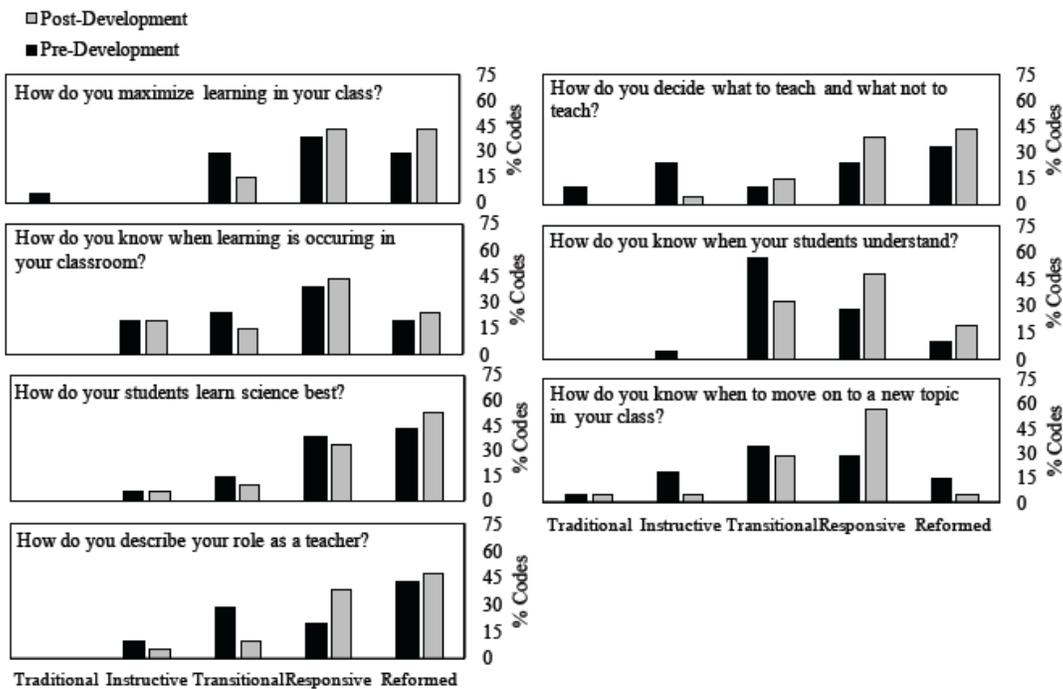
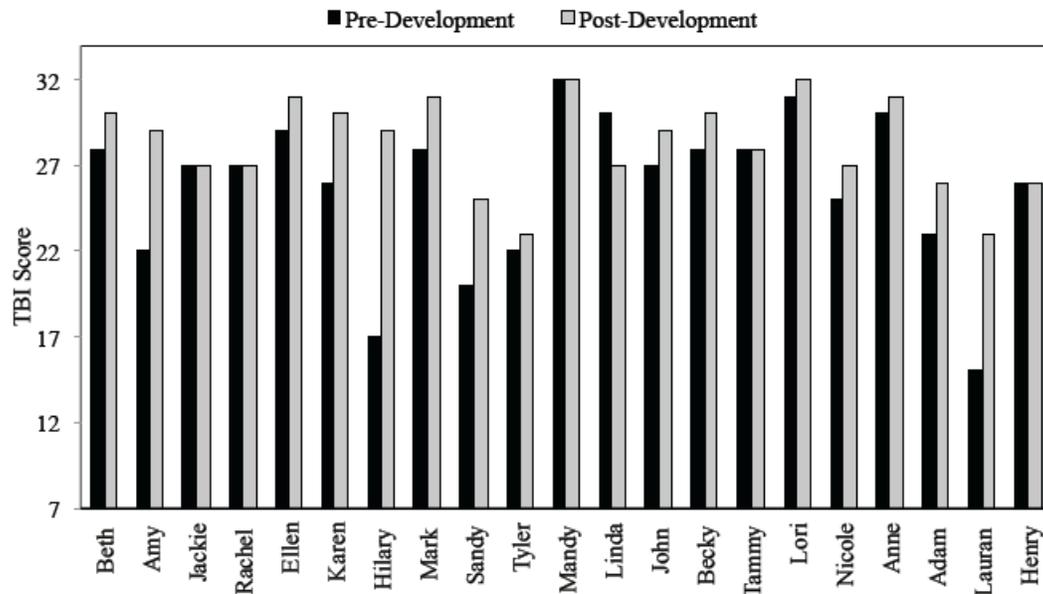
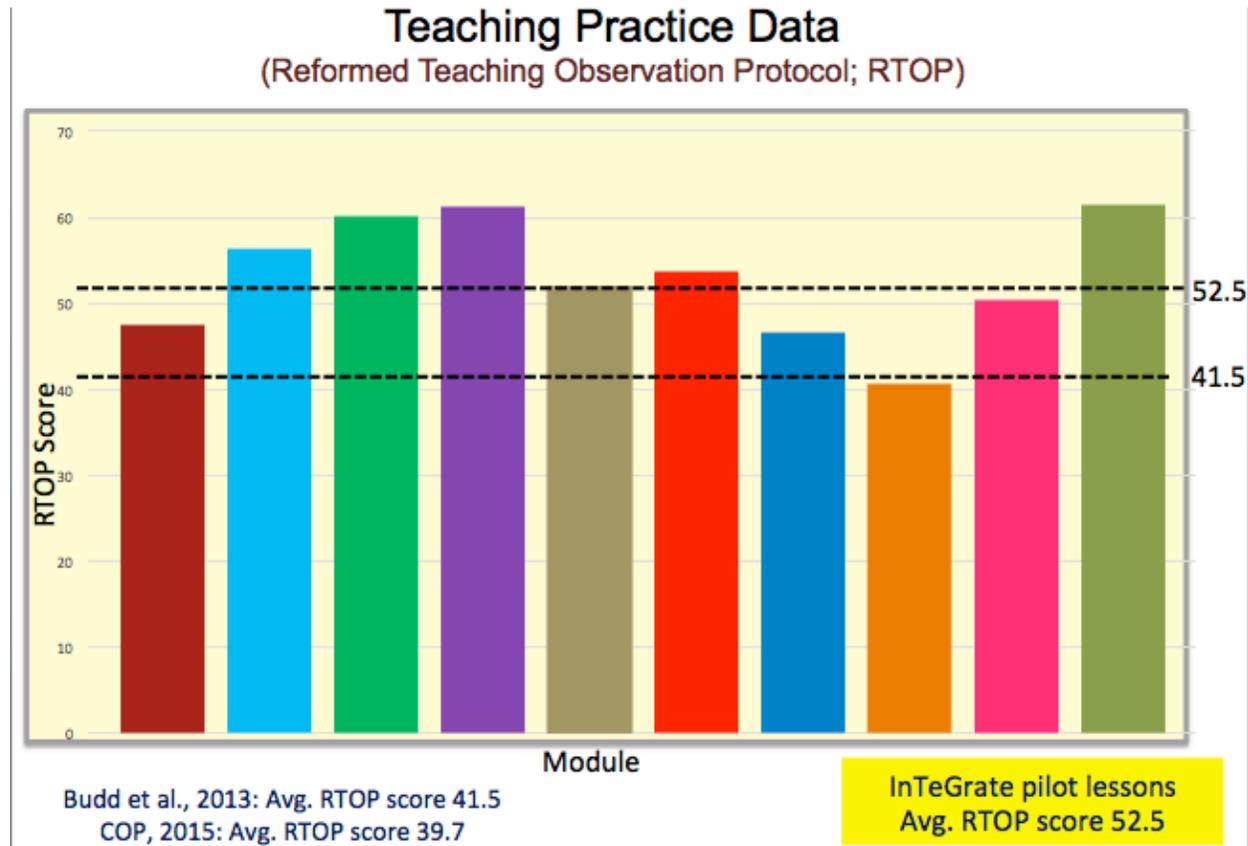


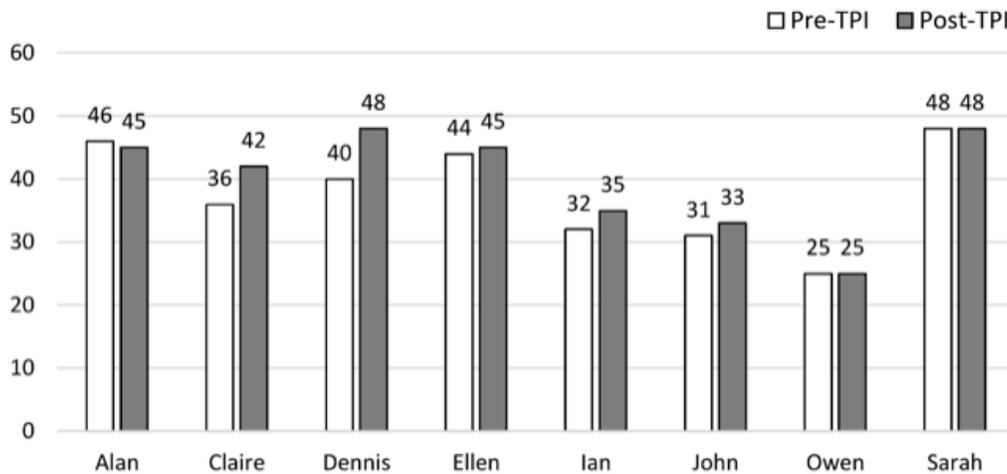
Exhibit II-12: RTOP data from pilot test enactments of ten introductory InTeGrate modules. Each color bar is the mean RTOP score for all of the observed sessions within one InTeGrate module. Twenty-one instructor/developers were observed for a total of 45 observations. The number of observations per module ranged from 1 to 8. (Unpublished data from David McConnell.)¹⁴¹ Mean RTOP across all 45 observations of InTeGrate instruction was 52.5 out of 100, well above a mean of 41.5 previously reported for a nationwide sample of Introductory geoscience courses (Budd, et al., 2013).



¹⁴¹ Unpublished data from David A. McConnell, presented at the InTeGrate Evaluation Summit, 23 May 2018, available at https://serc.carleton.edu/admin/private_download.php?file_id=91293 (restricted access). Also, emails from David McConnell to Kim Kastens, Oct 10 and Oct 12, 2018.

Exhibit II-13: Teaching practices data from the Research Team, a group of 8 faculty members who taught an Introductory level course without InTeGrate content (control semester) and then added 18 units of InTeGrate content to the same course (treatment semester). Names are pseudonyms. (*Upper*) TPI scores did not differ significantly from beginning of the project (pre- TPI) to end of the treatment semester (Post- TPI). (*Lower*) Mean RTOP scores during the treatment semester were significantly higher than during the control semester. From Czajka & McConnell (in review).

Teaching Practices Inventory Scores (max 67)



Reformed Teaching Observation Protocol Scores

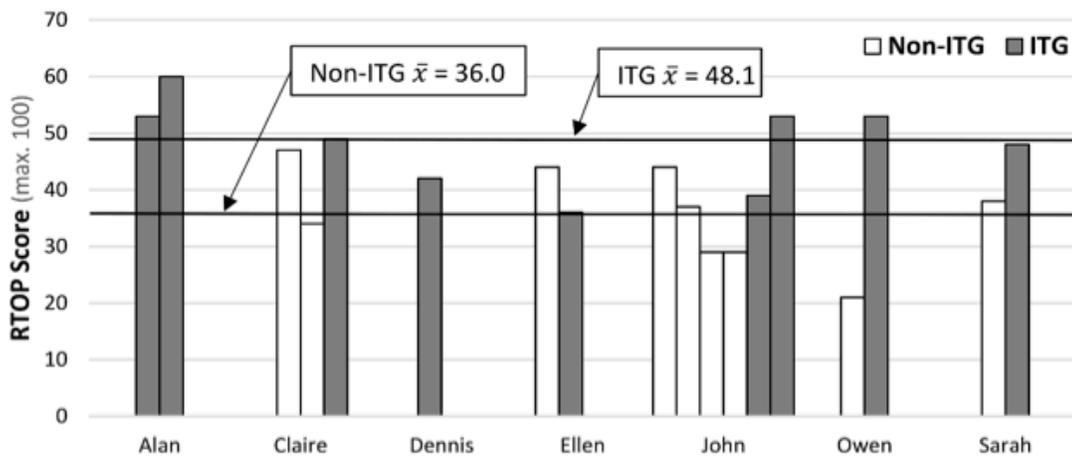


Exhibit II-14: Teaching beliefs data from the Research Team, faculty members who adopted/adapted InTeGrate instructional materials. Names are pseudonyms. (*Upper*) Two of the 8 participants (Alan and John) had a substantial shift (>6 TBI points) towards higher Teacher Beliefs Interview scores from the beginning to the end of the project, and 4 additional participants showed smaller increases. (*Lower*) TBI results disaggregated by interview question. The two questions in the left-hand column showed the biggest shift; the 2 questions in the right-hand column showed no shift; and the questions in the middle column showed small shifts.

Teacher Beliefs Interview Results

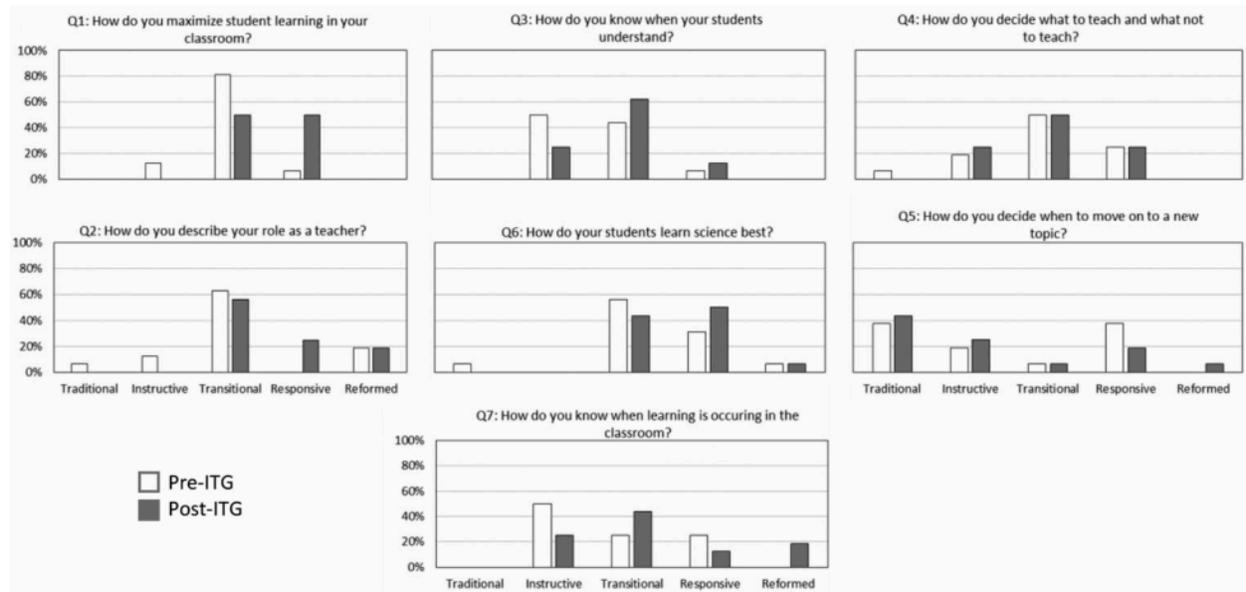
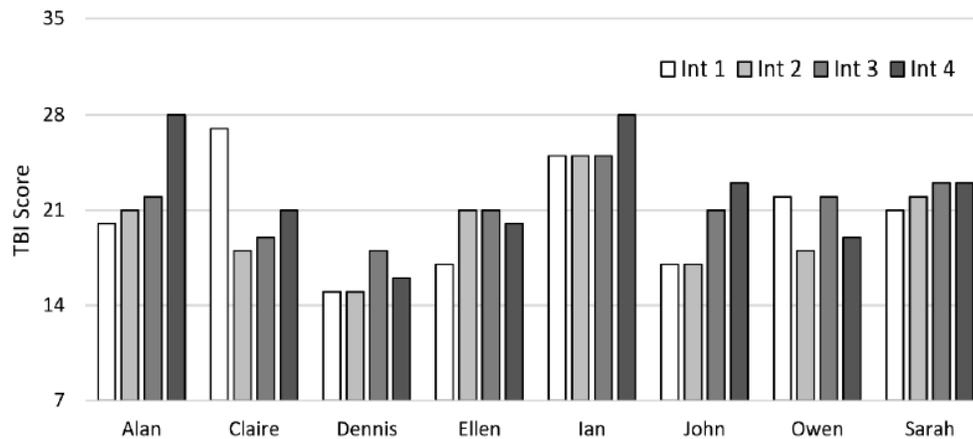


Exhibit II-15: NAGT’s National Survey of Geoscience faculty asked “in your most recent [intro/majors] class, did your students address a problem of national or global interest?” For both Intro (*Upper*) and Majors’ (*Lower*) responses, there was a steady increase over time in the percentage of “Yes” responses (black line). This trend predated InTeGrate, and continued at approximately the same rate during the InTeGrate era (2012 onward). In 2016, ITG SuperParticipants (“+” symbol) were more likely to have their students engage with problems of national or global interest than respondents who were not as involved, whereas the other groups clustered on or near the trendline.

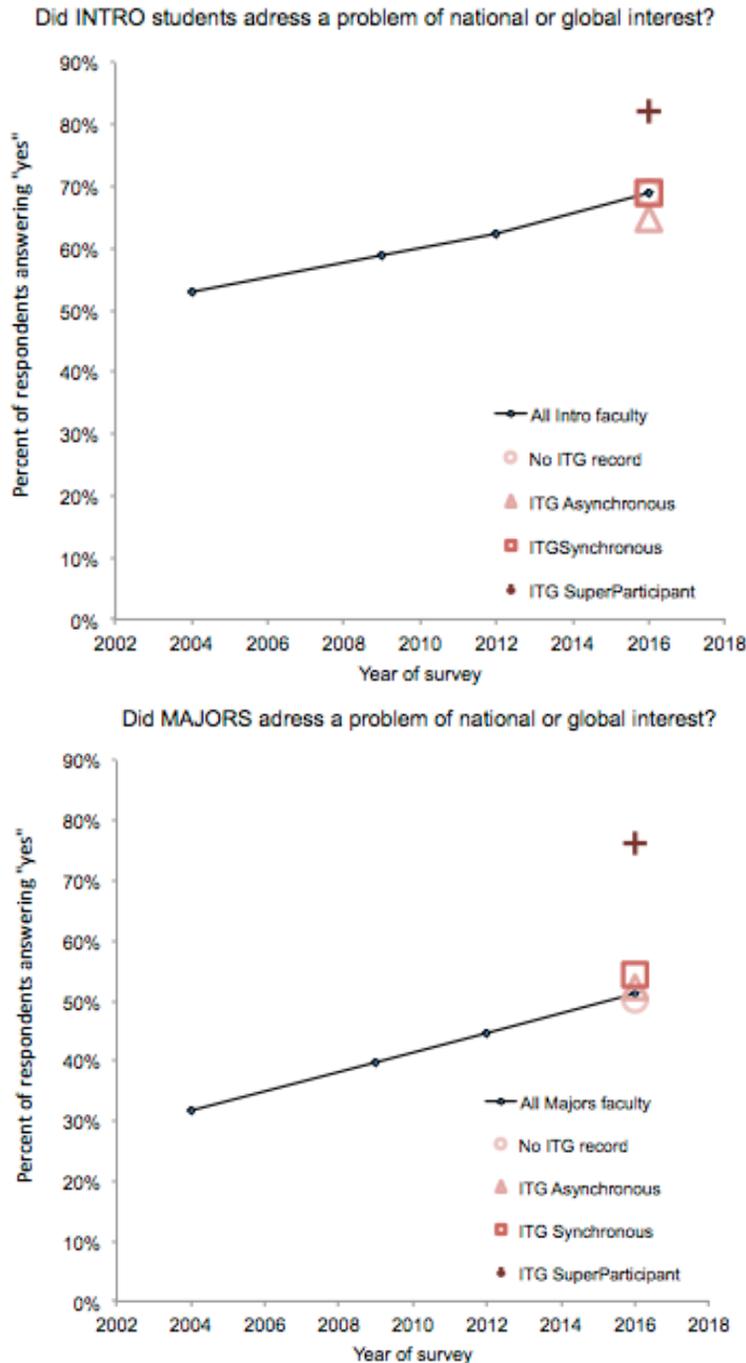


Exhibit II-16: On these six questions from the 2016 administration of the NAGT faculty survey, ITG Superparticipants were far more likely than any other respondent group to indicate that they used a teaching practice encouraged by InTeGrate, especially in their Intro courses. The top two rows show practices related to teaching about the Earth in a societal context; the bottom row concerns teaching systems thinking.

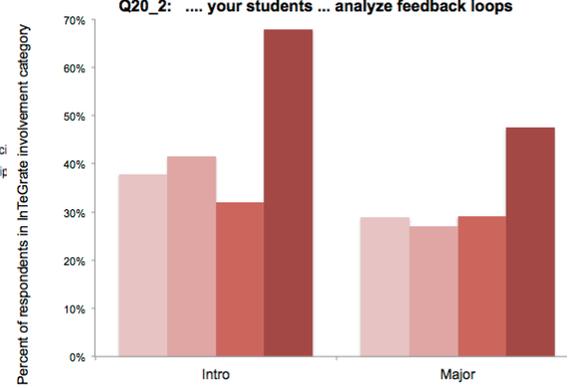
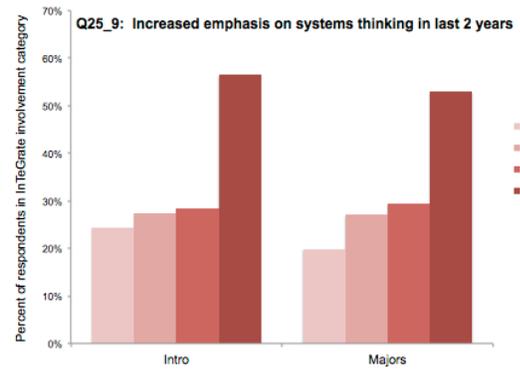
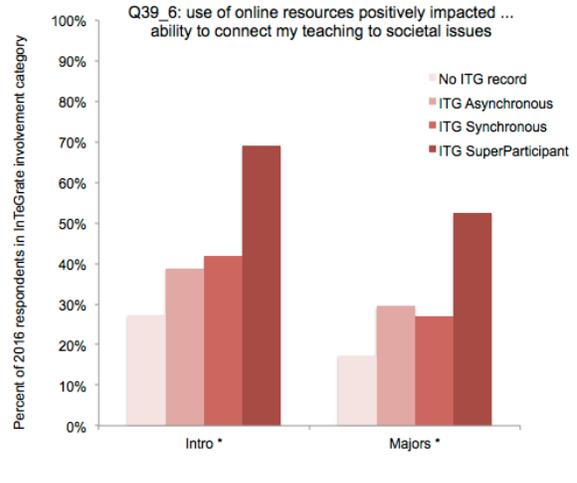
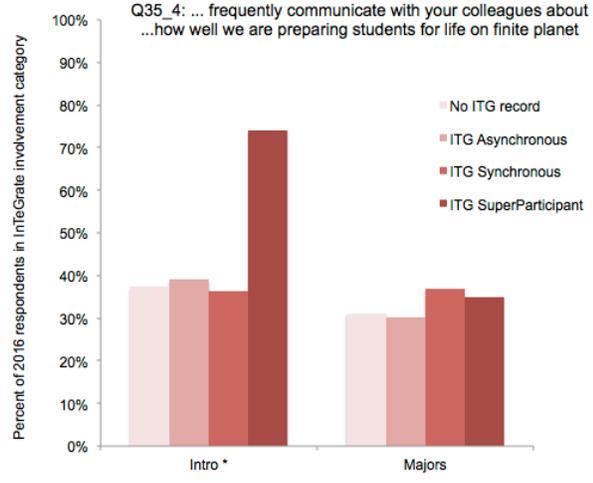
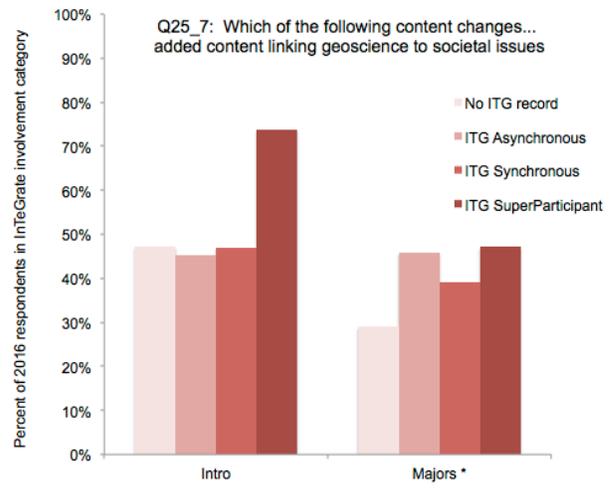
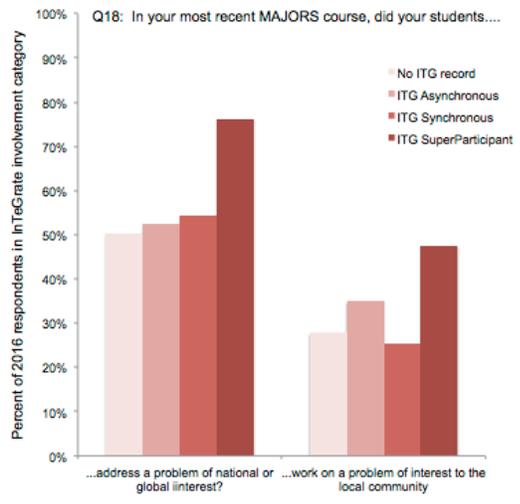


Exhibit II-17: The Fall 2016 administration of the NAGT Geoscience Faculty Survey asked respondents to answer with respect to their most recently taught course for Majors or for Intro students. By the end of 2015, when faculty would have had to make their major curriculum decisions for Spring 2016, only nine InTeGrate modules had been published. The other 23 courses or modules were in various stages of development, testing, or revision. (Figure from K. Sheriff, SERC.)

InTeGrate Materials Development Progression

32 modules/courses completed over 7 years

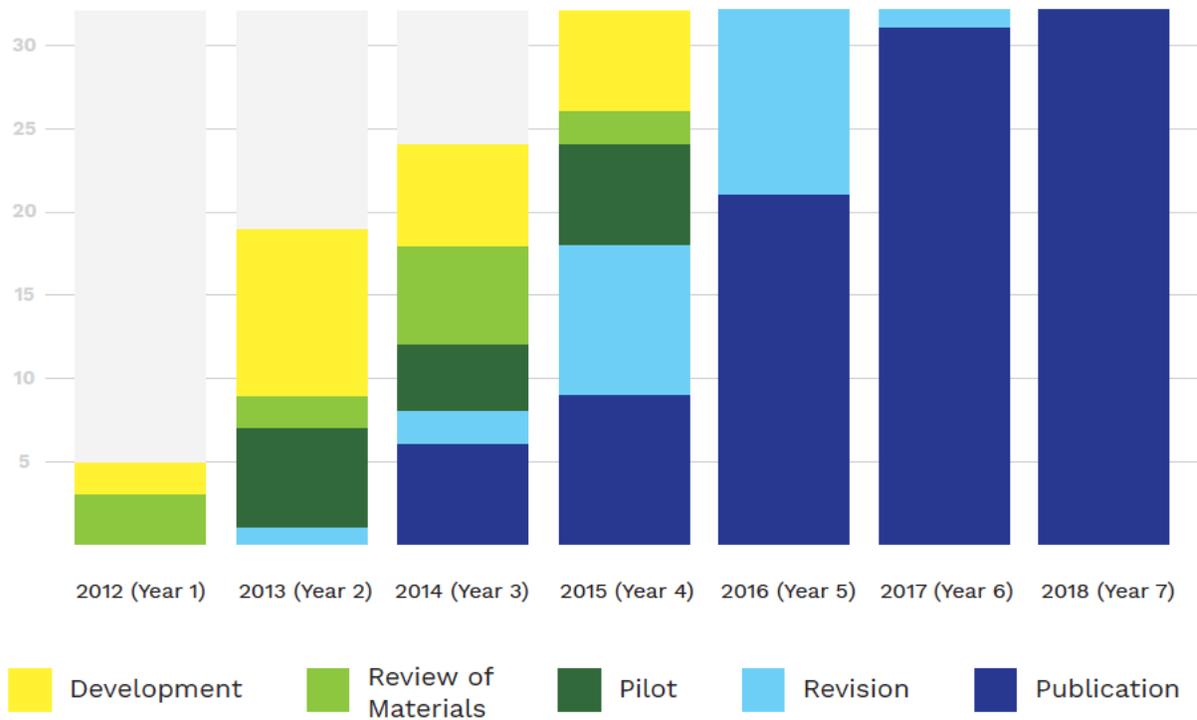


Exhibit II-18: Schematic design for data types collected by InTeGrate. From Iverson et al. (2019).

InTeGrate Assessment Data Collection Scheme

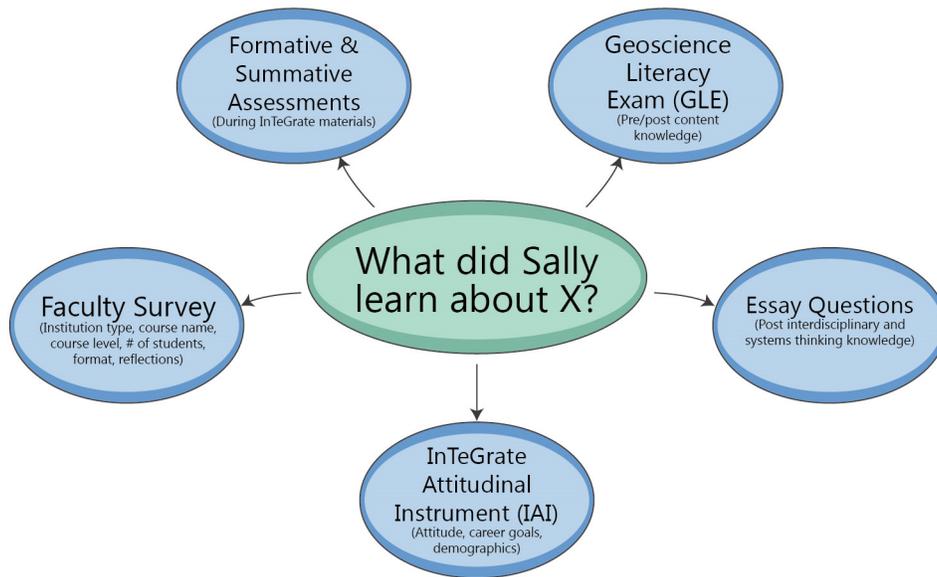


Exhibit II-19: Screen shot of the scorer’s eye view of the web-based tool that SERC developed to facilitate collaborative scoring of student essays. The scoring workload is divided up, and each scorer is assigned a group of essays to score, such that two scores are obtained per response. For each assigned student, the scorer sees the prompt, the student response (which can be enlarged), and a field in which to enter a numerical score and comments.

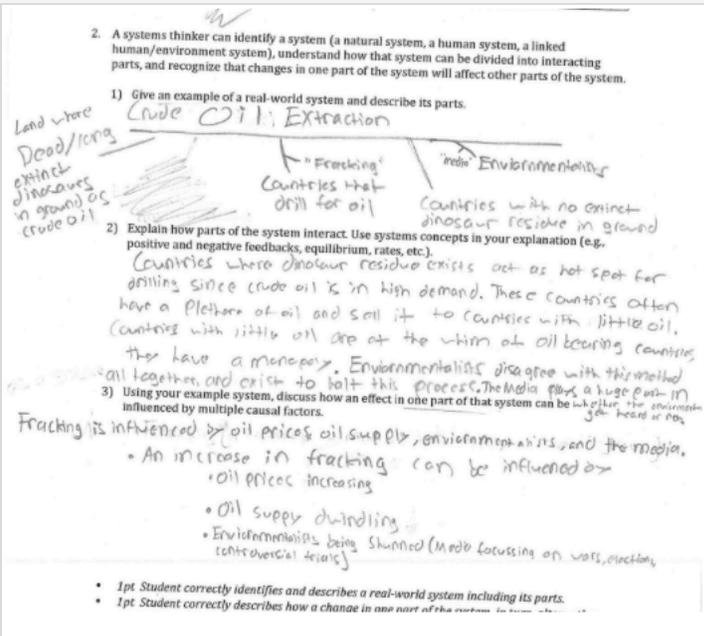
Grade Item ID: 351007 Question: 217 — [View Question 217 Rubric \(opens new tab\)](#)

A systems thinker can identify a system (a natural system, a human system, a linked human/environment system), understand how that system can be divided into interacting parts, and recognize that changes in one part of the system will affect other parts of the system.

1. Give an example of a real-world system and describe its parts.
2. Explain how parts of the system interact. Use systems concepts in your explanation (e.g., positive and negative feedbacks, equilibrium, rates, etc.).
3. Using your example system, discuss how an effect in one part of that system can be influenced by multiple causal factors.

Save

Hide Response »



2. A systems thinker can identify a system (a natural system, a human system, a linked human/environment system), understand how that system can be divided into interacting parts, and recognize that changes in one part of the system will affect other parts of the system.

1) Give an example of a real-world system and describe its parts.
Crude Oil: Extraction

Land where extinct dinosaurs in ground as crude oil

"Fracking" Countries that drill for oil

Environmentalists

Countries with no extinct dinosaur residue in ground

2) Explain how parts of the system interact. Use systems concepts in your explanation (e.g., positive and negative feedbacks, equilibrium, rates, etc.).
 Countries where dinosaur residue exists act as hot spot for drilling since crude oil is in high demand. These countries often have a plethora of oil and sell it to countries with little oil. Countries with little oil are at the whim of oil bearing countries they have a monopoly. Environmentalists disagree with this method all together and exist to halt this process. The media plays a huge part in

3) Using your example system, discuss how an effect in one part of that system can be influenced by multiple causal factors.
 Fracking is influenced by oil prices, oil supply, environmentalists, and the media.
 • An increase in fracking can be influenced by
 • Oil prices increasing
 • Oil supply dwindling
 • Environmentalists being shunned (media focusing on wars, election, controversial issues)

• 1pt. Student correctly identifies and describes a real-world system including its parts.
 • 1pt. Student correctly describes how a change in one part of the system is influenced by multiple causal factors.

Score

[Show All Responses](#)

Comments

(a) 1 pt. Interesting inclusions: media, environmentalists, as well natural (oil) and political boundaries. Oil from extinct dinosaurs is wrong--but it's not a systems thinking error.

[View full image \(opens new tab\)](#)

Exhibit II-20: Number of students who gave consent and who submitted at least one usable assessment (pre/post- GLE, pre/post- IAI, essay questions, summative assessment) that reached project headquarters. Each bar represents one module or one course. Alternative versions of the same module have been combined.

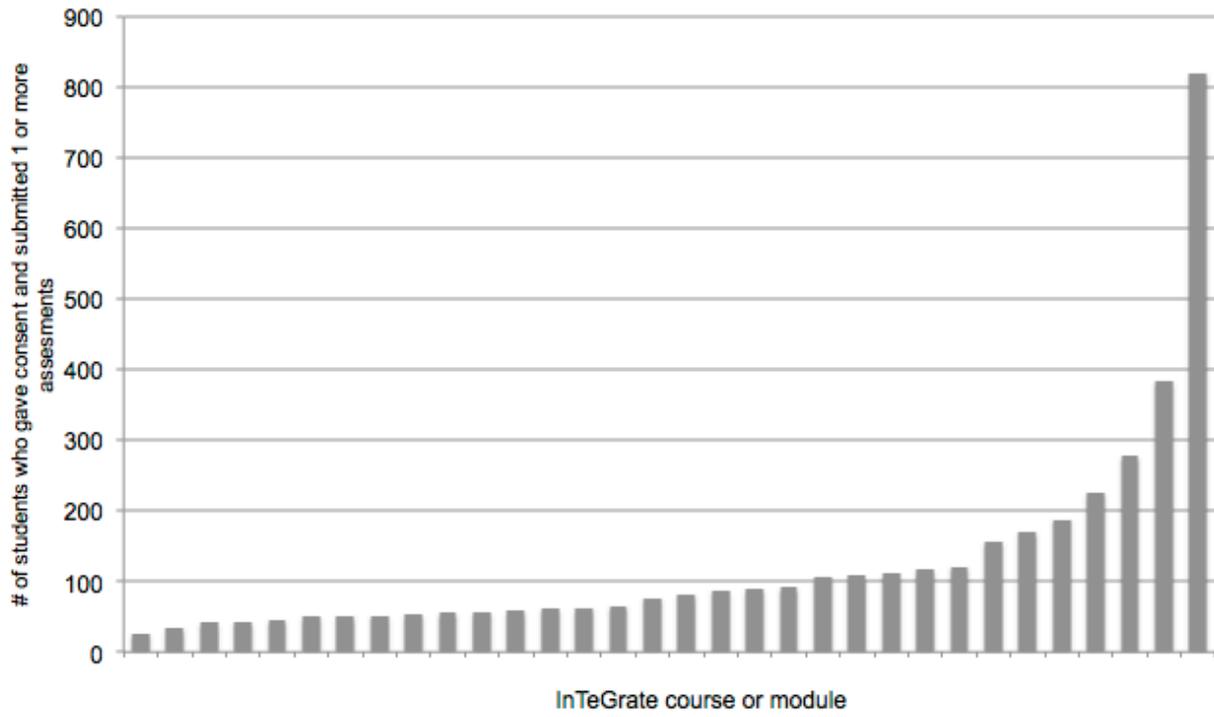


Exhibit II-21: Examples of the feedback provided by the Assessment Team on student responses to the summative assessments. Feedback covered both the apparent effectiveness of the assessment itself and the degree of student learning indicated by the assessment responses.

The summative assessment looks at the degree to which student have met the following module objectives: [Then the module objectives were enumerated, verbatim from the instructional materials.]

- With respect to objective 3 we have the following feedback: Most student responses did not create a persuasive argument, taking the approach that the “data speak for themselves.” As suggested above, perhaps both the summative assessment and the associated rubric could include specific required elements that asked students to introduce, define (using systems language and concepts), support (data), defend (argument), and conclude their analyses in more structured or formal ways that will also demonstrate a clear linkage with the Integrate goals. This may require additional language in the project description for students and perhaps even a short in-class exercise that demonstrates to students what an argument and how to support/defend that argument with data.
- With respect to objective 1 we have the following feedback: Many students did not discuss carbon exchange or reservoirs; or, if they did, they just named the reservoirs involved. None of the student work addressed climate changes in Earth’s history—but the prompt doesn’t explicitly invite a temporal comparison. We suggest modifying the prompt to describe how the proposed intervention would change the movement of carbon among Earth’s reservoirs.
- With respect to objective 3 we have the following feedback: We thought the students did a thorough job of responding to the assessment. The assessment does a thorough job of analyzing the different genres and audiences.

We also evaluated the degree to which the assessment and the student responses mapped to the InTeGrate guiding principles: [The 5 guiding principles were then enumerated.]

- With respect to guiding principle 5 (systems thinking) we have the following feedback: Only a few students used the language of systems thinking or defined their system through a concept or systems map demonstrating they had acquired an understanding of how this problem could be represented and explained through systems concepts. We suggest adding such a systems diagram so that students would have a sense that they are grappling with a system problem, not just an isolated local problem.
- With respect to guiding principle 2 (ability to address interdisciplinary problems) we have the following feedback: This project is extraordinarily interdisciplinary to the point where I think it is quite challenging for students to synthesize the information effectively. Most of the students note issues but do not directly connect science beyond noting high density or poverty or industry or utilities on waterfront. Student say "nuclear plant" but do not describe the risks. That said, this is a remarkable introduction to interdisciplinary thinking and reasoning through multiple and varied lenses.
- With respect to guiding principle 3 (methods of geoscience) we have the following feedback: The use of geoscience methods and habits of mind is implicit in the question, but the students spent more time in their responses critiquing these proposals based on economic/environmental reasons for accepting or rejecting a proposal. The way the assessment is written it does not *require* evaluation of geoscientific methods/habits. If the question focused them in more on the science behind the proposals/associated energy fluxes, then the critique would be an exercise of evaluating the observations, hypotheses, etc. proposed by the companies they’re critiquing, which would strengthen the assessment with regards to this principle.

Exhibit II-22: Wording of the two project-wide essay questions. The challenge in crafting these essay questions was to find probes that would capture learning across a wide range of topics at a wide range of competencies. The range of competencies to be probed was narrowed by giving the essay questions post-instruction only. The intention was that the rubric would be provided to the students along with the essay prompt, although this guidance was not universally followed.

Systems Thinking essay

Early Version:

Earth consists of interacting systems which exchange energy and/or mass at different rates and scales. Describe two interacting Earth systems emphasizing where, how, and how quickly they interact. Explain how a change in one system can drive change in the other system.

1 point: Correctly identifies 2 interacting systems

2 points: Correctly describes where, how, and how quickly the system interaction occurs

3 points: Links answer to feedback mechanisms

4 points: Response is constructed in a coherent and logical manner

Final Version:

A systems thinker can identify a system (a natural system, a human system, a linked human/environment system), understand how that system can be divided into interacting parts, and recognize that changes in one part of the system will affect other parts of the system.

(1) Give an example of a real-world system and describe its parts.

(2) Explain how parts of the system interact. Use systems concepts in your explanation (e.g., positive and negative feedbacks, equilibrium, rates, etc.).

(3) Using your example system, discuss how an effect in one part of that system can be influenced by multiple causal factors.

1pt Student correctly identifies and describes a real-world system including its parts.

1pt Student correctly describes how a change in one part of the system, in turn, alters other parts of the system.

1pt Student correctly explains how parts of the system interact using systems concepts such as feedbacks, equilibrium, rates, etc.

1pt Student describes how an effect can be influenced by multiple causal factors.

Inter-disciplinary Problem Solving Essay

Final Version:

Knowledge of Earth system interactions can influence how people make decisions about global challenges.

Identify and describe a global challenge that society will likely face in the next 50 years. Explain how the science related to that challenge informs economic, social, and/or political decision making related to the global challenge you described.

Your answer will be evaluated on the following 4-point scale:

- *1 Point: Student correctly states and suitably describes a global challenge*
- *1 Point: Student correctly identifies and explains one or more scientific implications related to the problem*
- *1 Point: Student appropriately connects the science to economic, social and/or political decisions*
- *1 Point: Student response is constructed in a coherent and logical manner*

Notes:

- Early version of systems essay from: Olson, T., and Egger, A., undated, Analyzing student responses from the Geoscience Literacy Exam, linked from https://serc.carleton.edu/integrate/info_team_members/research/index.html (restricted access)
- Final versions of the essay prompts are linked from: https://serc.carleton.edu/integrate/info_team_members/currdev/documents/gle/index.html (restricted access)

Exhibit II-23: Summary of questions asked on the pre- and post-instruction forms of the InTeGrate Attitudinal Instrument (IAI). From Iverson et al. (2019).

	<i>Pre-instruction</i>	<i>Post-instruction</i>
	1. What was your reason for taking this course?	
Career	2a. Have you chosen a college major yet? 2b. Please indicate whether you have or intend to declare a major in each of the following areas of study. [list]	1a. Have you chosen a college major yet? 1b. Please indicate whether you have or intend to declare a major in each of the following areas of study. [list]
	3: How interested are you in each of the following professions? [list]	2: How interested are you in each of the following professions? [list]
	4a. As you consider career directions after graduation, how important is it to you to do work in which you use your knowledge of the earth and environment? [7-point scale] 4b. As you consider employment after graduation, how important is it to you to work in an organization committed to environmentally sustainable practices (independent of the field)? Examples of environmentally sustainable practices would include minimizing energy and water use in the workplace. [7-point scale]	3a. As you consider career directions after graduation, how important is it to you to do work in which you use your knowledge of the earth and environment? [7-point scale] 3b. As you consider employment after graduation, how important is it to you to work in an organization committed to environmentally sustainable practices (independent of the field)? Examples of environmentally sustainable practices would include minimizing energy and water use in the workplace. [7-point scale]
		4. Which of the following graphs most accurately depicts your level of interest in a career in Earth or Environmental Sciences before and after taking this course or studying this module? [4 graphs]
Envi- ronment	5. Please indicate your level of concern about each of the following potential developments on the Earth. Focus on the impact on your region in your lifetime. [list]	5. Please indicate your level of concern about each of the following potential developments on the Earth. Focus on the impact on your region in your lifetime. [list]
	5a. Please indicate the extent to which you engaged in each of the following activities during the past week [list]	6a. Please indicate the extent to which you engaged in each of the following activities during the past week [list] 6b. When you engage in behaviors such as those listed in the previous question, what factors or sources of information influence your decision to do so? [list]
		7. People differ in how motivated they are to take action in their personal and professional lives to create a more environmentally sustainable society. Which of the following graphs best represents your degree of motivation before and after taking this course or studying this module? [4 graphs]
		8. As you think about your future, can you envision using what you have learned in this course to help society overcome problems of environmental degradation, natural resources limitations, or other environmental issues? If yes, how? If not, why not? [open response]
Demo- graphics	<ul style="list-style-type: none"> • Gender [list] • Ethnicity [list] • Race [list] • Year in college: [list] • Age [open] 	

Exhibit II-24: Normalized pre/post change scores on the GLE-16 from the Research Team, during the semesters when they did and did not include InTeGrate materials in their course. (*Upper*) Female participants experienced more improvement in geoscience literacy under the InTeGrate condition (treatment) than they did without InTeGrate (control); males did not show this effect. (*Lower*) Likewise, students who identified as Hispanic experienced more improvement in geoscience literacy under the ITG condition than they did without ITG; non-Hispanics did not show this ITG effect. Data from Czajka (2018).

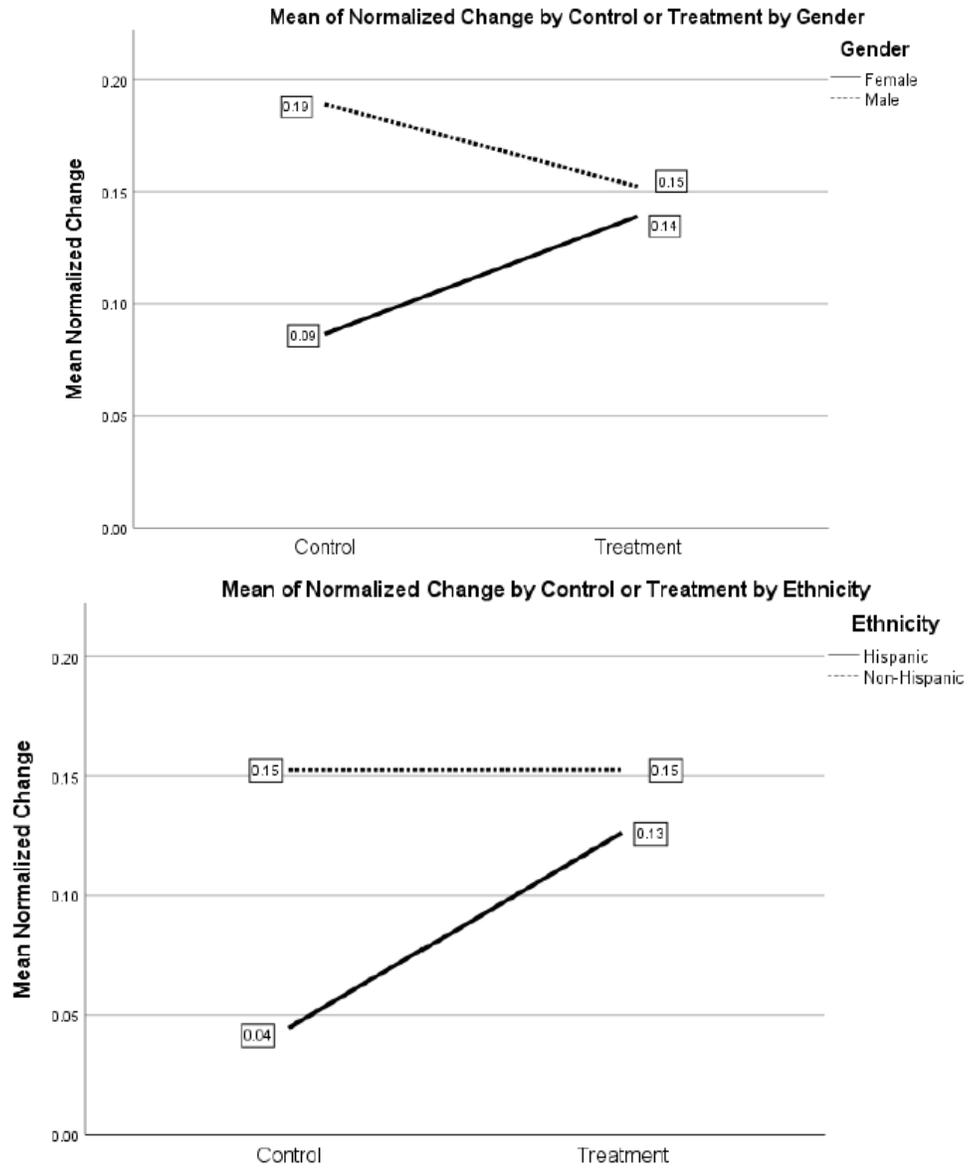


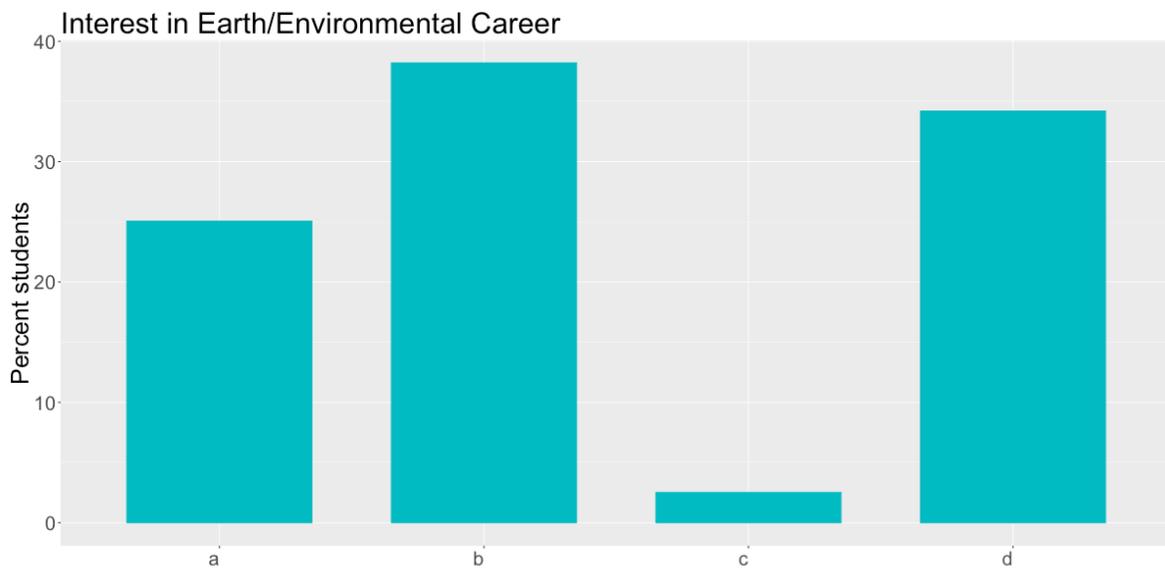
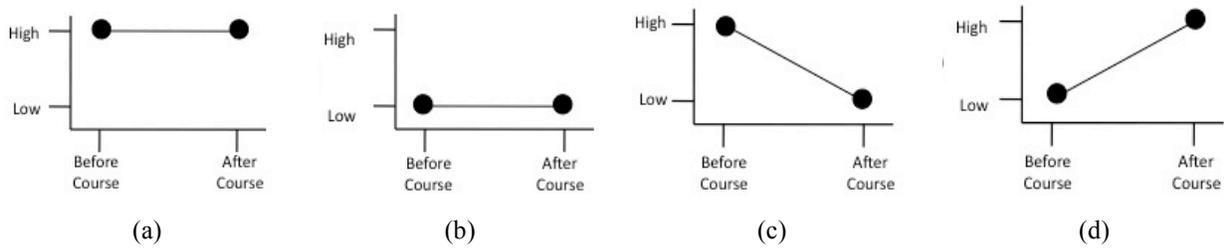
Exhibit II-25: Matrices showing changes from pre- to post-instruction in respondents' level of interest in majoring in Environmental Science/ Environmental Studies (*Upper*) and Geosciences (*Lower*). Each respondent appears once in each matrix, positioned according to his/her level of interest pre-instruction (which determines his/her row in the matrix) and level of interest post-instruction (which determines his/her column in the matrix). The white cells along the diagonal contain students whose interest in the major did not change across instruction (the majority of the students). Green cells contain students who increased their level of interest in the major, whereas orange cells contain students whose interest decreased. The rectangle across the bottom shows the total movement towards and total movement away from the major.

Environmental Science/ Studies Major		Post-instruction		
		Will not choose	Might choose	Definitely or probably
Pre-instruction	Will not choose	56.3% (1,153)	7.4% (151)	1.7% (34)
	Might choose	6.5% (133)	9.4% (193)	2.5% (49)
	Definitely or probably	1.8% (37)	2.1% (42)	12.5% (256)
		Total towards Env S/S: 11.6% Total away from Env S/S: 10.4%		

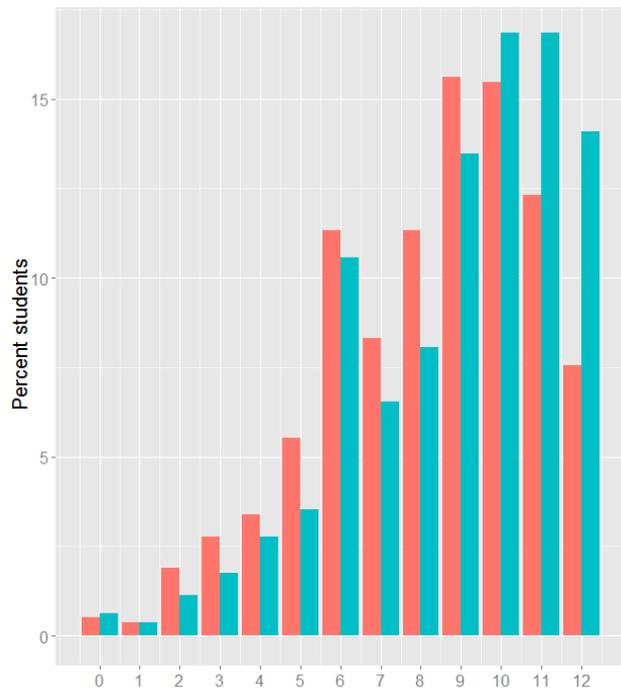
Geosciences Major		Post-instruction		
		Will not choose	Might choose	Definitely or probably
Pre-instruction	Will not choose	69.7% (1,372)	5.5% (108)	2.1% (41)
	Might choose	6.6% (130)	7.4% (145)	1.2% (24)
	Definitely or probably	1.8% (36)	1.2% (24)	4.5% (89)
		Total towards Geo: 8.8% Total away from Geo: 9.7%		

Exhibit II-26: When offered, post-instruction, a choice of four graphs to indicate if and how their interest in a career in Earth or Environmental Sciences has changed from before to after the course, approximately a third of respondents indicated that their level of interest had gone from low to high across instruction.

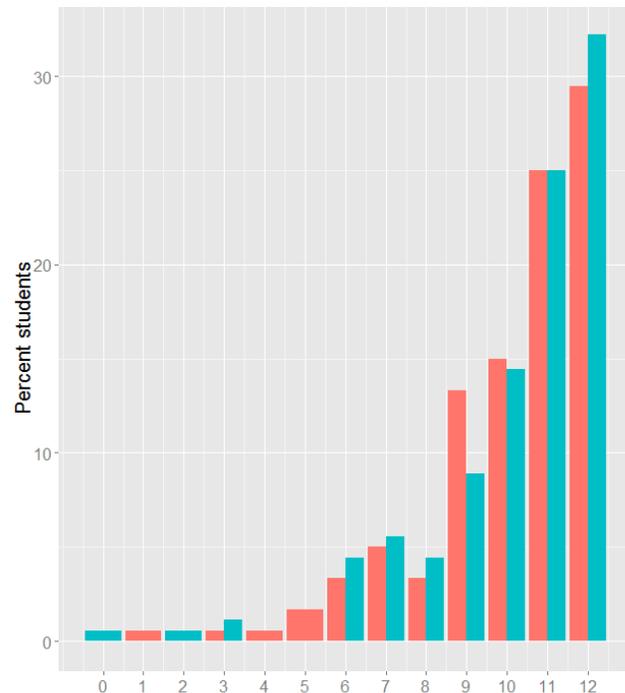
Item 4: Which of the following graphs most accurately depicts your level of interest in a career in Earth or Environmental Sciences before and after taking this course or studying this module?



*Exhibit II-27: Contrast in Environmental Concern Index between two subsamples who took the course for different reasons, with pre-instruction in red and post-instruction in blue. The Environmental Concerns Index is constructed by awarding zero points for “no problem,” one point for “somewhat of a problem,” and two points for “major problem,” on the item where respondents indicated their level of concern about six issues that most environmental scientist would consider to be issues of concern. The group who took the course only to satisfy a Gen Ed or distribution requirement (*left*) had relatively low Environmental Concerns Index prior to instruction and increased substantially by the end of the course. The group who took the course for Major + Career + Personal Interest (*right*) was already close to ceiling on this measure before instruction and did not change significantly across instruction.*



Students who took course for Gen Ed only



Students who took course for Major + Career + Personal Interest

Exhibit II-28: Data from Pelch & McConnell (2017) in which students' attitudes toward science were measured in a Physical Geology course taught by the same instructor without (control) and then with (treatment) InTeGrate materials. (*Upper*) Data from the Change in Attitude about the Relevance of Science (CARS) survey. CARS showed a significant increase across instruction in both treat semesters (TS1 and TS2)—but so did scores from one of the control semesters (CS2). (*Lower*) Scores on the Revised Scientific Attitude Inventory (SAI II); vertical axis is Person Measures (logits) from Rasch analysis. Attitudes got worse across instruction in the Control semesters and in the first Treatment semester, as had been seen in other studies of Intro level college science courses using this instrument. SAI attitudes were unchanged across instruction in the second treatment semester.

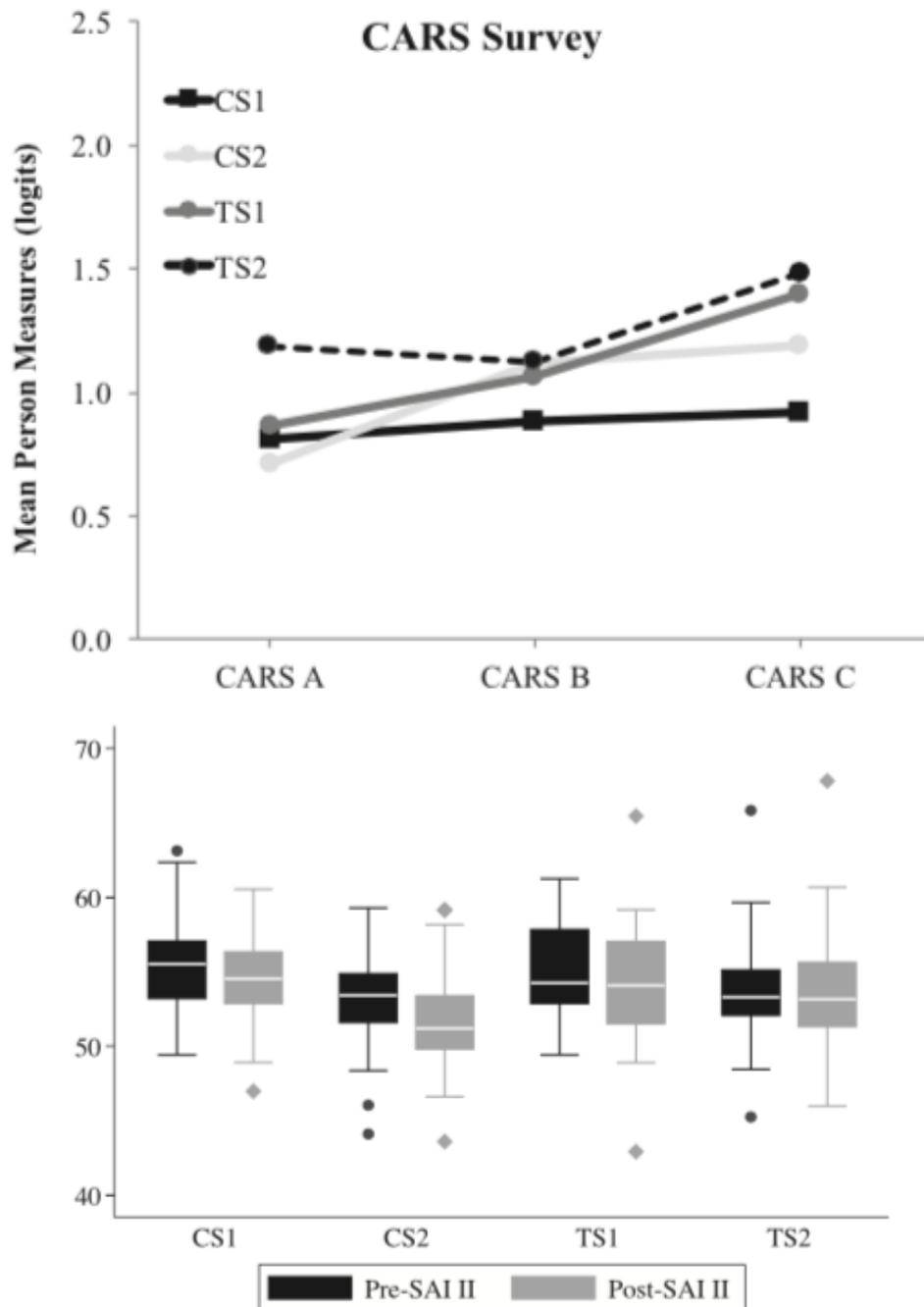


Exhibit II-29: (from Gilbert et al, in prep). (A & B) Bubble plots of post-instruction Geoscience Literacy Exam (GLE) score and Systems Thinking Essay score from students enrolled in courses without InTeGrate materials (Control; n=173) and with InTeGrate materials (InTeGrate; n=360). Bubble area is proportional to % of students from each type of course, as shown in the legend to the right. (C) Model of the relationship between GLE and Systems Thinking score ($y=x/3$; RMSE=1.25). (D) Model superimposed on data. Bubbles within the green shaded area demonstrate systems thinking in proportion to their geoscience literacy. Those in the gray upper left corner demonstrate significantly stronger systems thinking than predicted by the model; those in the unshaded lower right demonstrate significantly weaker systems thinking than predicted by the model. (E) Percent of students from each type of class that fit the model (green): 65% from InTeGrate classes and 11% from Control classes. Notably, 89% of students from control classes demonstrate very weak systems thinking (white).

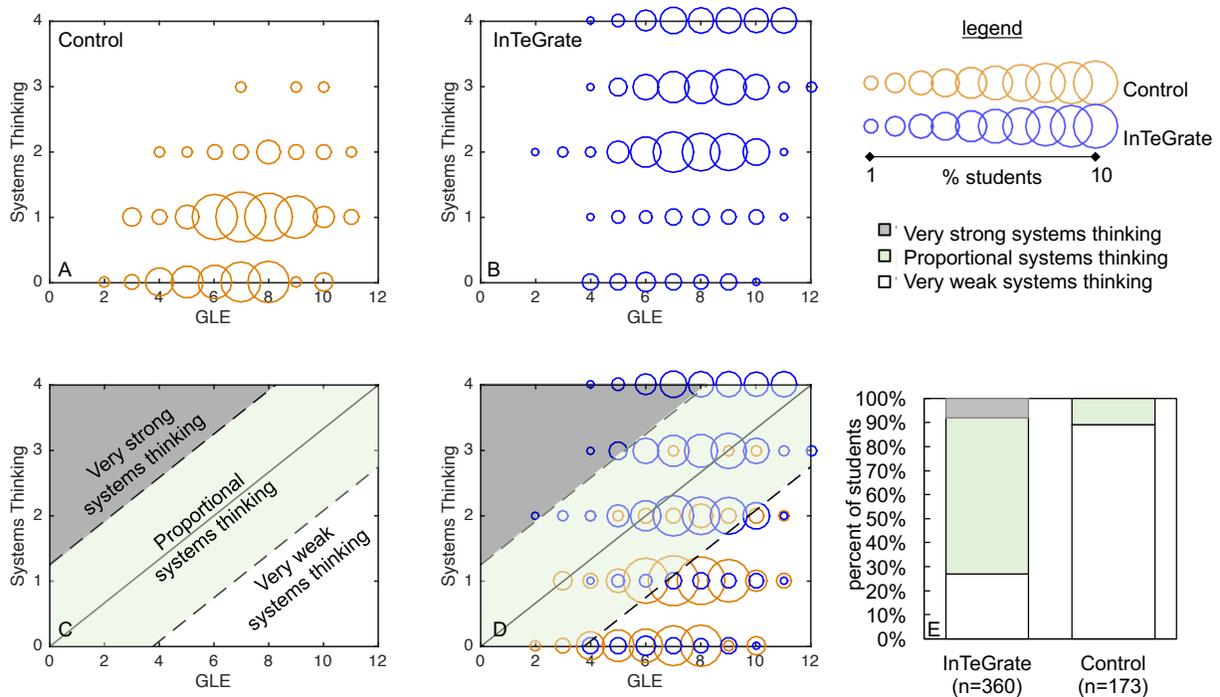


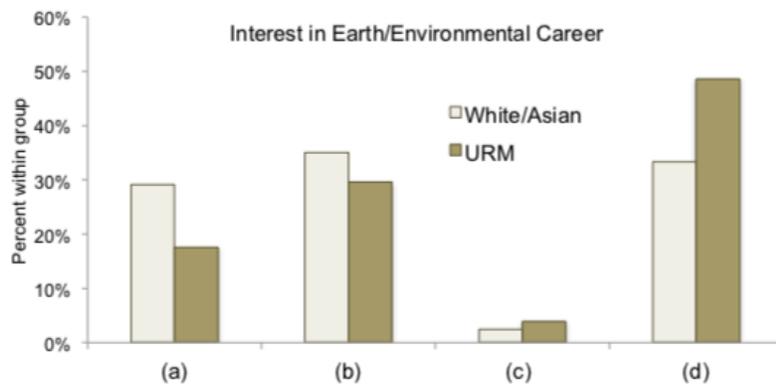
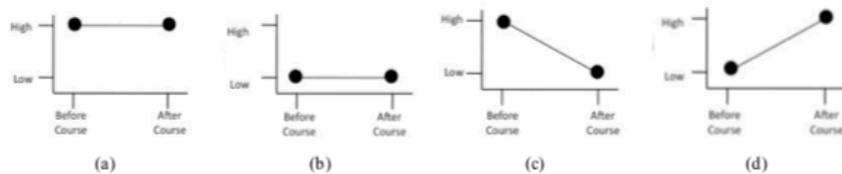
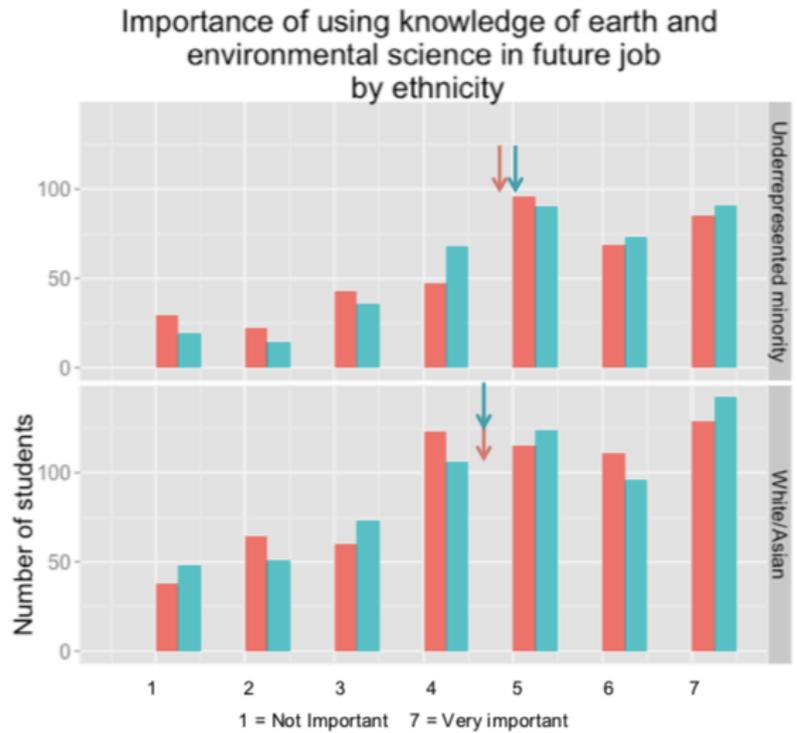
Exhibit II-30: The semester-long, upper-division Critical Zone Science course offers an unusual dataset in which both InTeGrate essay questions were offered both pre- and post-instruction, and on a pilot-test enactment as well as on a post-revision enactment, at the same university with the same instructor/developer. Students were upper division undergraduates or Masters students in geology, geography, or environmental studies, so the questions were within their grasp pre-instruction, which would not have been the case in the typical intro-level InTeGrate course. Learning gains were stronger on the post-revision enactment than during the pilot testing phase.

	Fall 2015: pilot testing		Spring 2017: post-revision	
	% answered correctly		% answered correctly	
	Pre-course	Post-course	Pre-course	Post-course
InTeGrate interdisciplinary problem-solving essay	13	25	17	75
InTeGrate systems essay	20	50	33	88

Notes:

- Data from Dere, et al. (2019). Clarification of scoring: email with Ashlee Dere, 22 and 30 January 2019.
- N=12 both semesters
- For the work reported in the Dere et al. paper, the systems essay was scored as “answered correctly” if the student described/illustrated a system that included reservoirs and fluxes.
- The interdisciplinary problem-solving essay was scored as “answered correctly” if the student both identified a grand challenge and discussed science that could help address the grand challenge (also, the science had to be accurate). This essay was modified in 2017 to more explicitly ask about Critical Zone Science, rather than just “science.”

Exhibit II-31: Comparison of URM versus non-URM students on two IAI items related to career interest. (Upper) When asked how important is it to you to do work in which you use your knowledge of the earth and environment, URM's placed a higher importance on such work pre-instruction (red) and even more so post-instruction (blue). (Lower) When asked to choose among four graphs depicting level of interest in a career in Earth or Environmental Science before and after taking this course, URM's were more likely than non-URM's to indicate that their interest had increased across instruction.



Chapter 3

Claim #2: InTeGrate has expanded the reach of high-quality Earth education opportunities.

Claim #2 says that InTeGrate materials, program models, ideas, habits of mind, professional development opportunities, and other efforts have collectively increased the fraction of America's undergraduate students who have the opportunity to experience high-quality Earth education. Whereas Claim #1 was about improving the curriculum and teaching practices through which Earth education is delivered, Claim #2 is about how widely such high quality Earth education is delivered. Evaluating the reach of InTeGrate's materials and ideas is important, because many educational programs achieve high learning gains within a relatively small study population but fail to scale up to a nation-wide audience.¹

Claim 2 encompasses the following components:

- *Sub-Claim 2A: InTeGrate has increased the nation's capacity for preparing pre-service K-12 educators to teach about the Earth through undergraduate education of future teachers.*
- *Sub-Claim 2B: InTeGrate has created materials and models for infusing teaching about the Earth into humanities, social sciences, STEM disciplines outside of Geosciences, and interdisciplinary contexts.*
- *Sub-Claim 2C: InTeGrate has reached underrepresented minorities who might otherwise have had limited access to quality Earth education, and has built capacity to attract and support diverse students along their path towards geo-literacy and/or the geoscience workforce.*
- *Sub-Claim 2D: InTeGrate has created models for providing Earth learning opportunities for students at institutions that have no geo department or limited geo faculty.*
- *Sub-Claim 2E: Individual faculty nationwide are finding, accessing, and using quality Earth-related curriculum resources, pedagogical strategies, and program-strengthening strategies, via InTeGrate's websites, publications, and webinars.*

Claim #2 places particular emphasis on reaching high-leverage audiences. Sub-claim 2A looks at future K-12 teachers, because they offer a strong multiplier effect as they spread a deeper understanding of the Earth and environment to future generations. Moreover, if K-12 Earth education becomes more relevant and more widespread, a higher percentage of students may come to college with an inclination to study geoscience.

Sub-claim 2B looks at reaching students who might not find their way to the geoscience department on their campus, reaching out to them wherever they might be: in another STEM field, in humanities or social sciences, and especially in interdisciplinary programs and offerings. The rationale is: (a) some of those students could become geoscience majors, (b) practitioners in all fields, as well as voters and consumers, should be able to take the limitations of Earth systems into account in their own decision-making, and (c) many of today's complex environmental and resource grand challenges require insights from many disciplines.²

¹ Cohen, D. K., & Ball, D. L. (2006). Educational innovation and the problem of scale. In B. Schneider & M. Sarah-Kathryn (Eds.), *Scale Up in Principle, Volume 1*. Rowman & Littlefield, pp. 19-36, and references therein.

² Gosselin, D. C., Manduca, C., Bralower, T. J., & Egger, A. E. (2019). Preparing students to address societally-relevant challenges in the Geosciences: The InTeGrate approach. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.),

Sub-claim 2C addresses InTeGrate's reach to communities underrepresented in STEM, contributing to the NSF-wide effort to broaden access and success for all students. Sub-claim 2D looks at models for reaching students in schools that have few or no geoscience faculty, which is important because only 22% of U.S. degree-granting institutions of higher education reported having a geoscience department.³ Many institutions have one or a few faculty teaching Earth-related courses, typically in non-geoscience departments, and InTeGrate saw supporting those isolated Earth educators as a high leverage opportunity. Sub-claims 2C and 2D are interrelated, because many minority-serving institutions fit the profile of having few or no geoscience faculty.

Sub-claim 2E grapples with trying to document InTeGrate's entire reach. This includes the difficult-to-quantify group of educators who were not part of any paid InTeGrate professional development opportunity, but who accessed InTeGrate materials or ideas on their own.

Two strategies recur across sub-claims and were central to InTeGrate's approach to attracting and supporting new constituencies for teaching about the Earth in the context of societal issues. These were: first, to gather, synthesize and disseminate best practices, and second to build Implementation Programs that focused on new audiences. Some overarching thoughts about these two practices will be followed by a deeper dive into each sub-claim.

About InTeGrate's gather-synthesize-disseminate best practices strategy

Sub-claims 2A (K–12 teachers), 2B (interdisciplinary contexts), and 2C (diversity) all begin with a section about how InTeGrate has gathered, organized and synthesized, and then disseminated information about how individuals and programs can expand the effective reach of high quality Earth education to an important audience. As this strategy recurs multiple times in the InTeGrate system, a few overarching thoughts are in order.

This InTeGrate strategy builds upon years of similar work by earlier SERC-supported programs, most notably *On the Cutting Edge*, and *Building Strong Geoscience Departments*.⁴ In each of these earlier programs, as well as in InTeGrate, workshops are used as a mechanism for casting a wide net to gather insights, ideas and resources that had been widely dispersed in the minds and practices of faculty across the nation. Mechanisms for capturing these treasures include asking participants to contribute essays, activities, course descriptions, program descriptions, syllabi, data sheets, and teaching method descriptions, and to engage in deep discussions around specific issues. Participants capture discussion notes, in real time, into the workshop website. Workshop conveners and/or SERC staff then take this rich, bulky, raw material, combine it with relevant insights from the literature, and distill it down into a concentrated essence, rich in actionable suggestions. This essence is then published on the InTeGrate website,⁵ where it can serve as an aide-mémoire for people who did attend the workshop, and an on-ramp for others who did not.

Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future. Switzerland: Springer, pp. 3-24.

³ McDaris, J., Manduca, C. A., Iverson, E., & Orr, C. H. (2017). Looking in the right places: Minority-serving institutions as sources of diverse Earth Science Learners. *Journal of Geoscience Education*, 65(4), pp. 407-415.

⁴ Manduca, C. A., Mogk, D. W., Tewksbury, B., Macdonald, R. H., Fox, S. P., Iverson, E. R., . . . Bruckner, M. (2010). On the Cutting Edge: Teaching help for Geoscience faculty. *Science*, 327(5969), pp. 1095-1096. Manduca, C. A., Iverson, E., Luxenberg, M., Macdonald, R. H., McConnell, D. A., Mogk, D., & Tewksbury, B. (2017). Improving undergraduate STEM education: The efficacy of discipline-based professional development. *Science Advances*, 3, e1600193. *Building Strong Departments*: <https://serc.carleton.edu/departments/index.html>. *On the Cutting Edge*: <https://serc.carleton.edu/NAGTWorkshops/index.html>.

⁵ Prepare Future Teachers: <https://serc.carleton.edu/integrate/programs/teacherprep/index.html>. Interdisciplinary Teaching: Designing for Success: https://serc.carleton.edu/integrate/teaching_materials/interdisciplinary.html. Increase the diversity of your Graduates: <https://serc.carleton.edu/integrate/programs/diversity/index.html>.

Much of the gathered material could be classified as “pedagogical content knowledge (PCK),” e.g. knowledge about how to effectively teach a body of content in a specific domain of knowledge.⁶ PCK is contrasted with “subject matter knowledge” and with generalized “pedagogical knowledge” about teaching methods. PCK can be thought of as the specialized knowledge that distinguishes a teacher from a content area specialist, or a great teacher from a good teacher, or an experienced teacher from a novice. One way to conceptualize what InTeGrate (and its precursor projects) have been doing is methodically gathering, organizing and sharing PCK for the geoscience content domain, shortcutting the process by which college instructors are so often left on their own to figure these things out by trial and error.

The process by which teachers develop their PCK through experience, reflection, professional development, or other means is lightly-researched and not well understood, in part because the PCK of a given instructor is so hard to measure. InTeGrate has implicitly rejected the idea that PCK can only be constructed by the individual teacher through experience. On the contrary, InTeGrate and Cutting Edge are built around the premise that PCK can be shared and reused, and that it is beneficial to do so.

InTeGrate’s strategy for changing of teaching beliefs and practices may best be described as “*a clear, simple, message, repeated often, by trusted sources.*”⁷ This approach is familiar to many geoscientists as the heuristic provided by communication researcher Edward Maibach for changing human beings’ beliefs and behavior about anthropogenic climate change. Behind this pithy phrase is a wealth of social science research documenting humans’ avoidance of cognitively difficult tasks, susceptibility to repetition, and reliance on trusted sources for guidance in decision making. InTeGrate’s “clear, simple message” is that students will be drawn to Earth education and learn better if you (a) use student-centered pedagogy, and (b) teach about the Earth in the context of societal issues. “Repeated often” is manifested as a theme running through multiple curriculum modules, web pages, workshops, webinars, IPs and traveling workshops. “Trusted sources” are fellow faculty or materials created by fellow faculty.

To this familiar “clear, simple” mantra, Maibach’s most recent work has added a second heuristic: “*Make the behavior you are promoting easy, fun and popular.*”⁸ This second heuristic is also backed by social science research documenting the importance of removing barriers to the desired behavior and providing demonstrations, the effectiveness of delivering benefits (i.e. “fun”) before costs are incurred rather than vice versa, and the power of social norms. This second heuristic is also a close match with InTeGrate’s *modus operandi*. The InTeGrate website provides multiple demonstrations of InTeGrate practices playing out in practice, as instructor stories, program models, and curriculum materials. Workshops make vivid that InTeGrate-aligned approaches are popular among leaders in the field, and can be fun. Educative, freely-available curriculum materials make adopting the behavior easy--or at least easier than inventing effective instructional practices all on your own.

⁶ Cochran, K. F. (1997). Pedagogical Content Knowledge: Teachers' integration of subject matter, pedagogy, students and learning environments. *Research Matters--to the Science Teacher* (9702). Retrieved from <https://www.narst.org/publications/research/pck.cfm>. Shulman, L. S. (1987). Knowledge and Teaching: Foundations of the New Reform. *Harvard Educational Review*, 57, pp. 1-22. Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *PCK and Science Education*. The Netherlands: Kluwer Academic Publishers.

⁷ This formula or heuristic for changing complex, consequential behavior comes from Edward Maibach of the George Mason University Center for Climate Change Communication. In its application to climate change, it is broadly familiar to the geoscience community. The rationale for this approach is spelled out in Maibach, E. (2017). Increasing public awareness and facilitating behavior change: Two guiding heuristics. In L. Hannah & T. Lovejoy (Eds.), *Climate Change and Biodiversity*. New Haven: Yale University Press, also available online at: <https://www.climatechangecommunication.org/wp-content/uploads/2018/06/Maibach-Two-heuristics-September-2015-revised.pdf>.

⁸ Maibach (2017) *op cit.*, taken from Smith, B, Reinventing social marketing. TedX Penn Quarter, (2011). <https://www.youtube.com/watch?v=IECY9LJvTf4>

About Implementation Programs⁹

Much of InTeGrate's work in support of Claim 2 has been done in the context of InTeGrate's Implementation Programs (IPs), and so some overarching comments about IPs now follow. "Implementation Program" was a new concept for the GeoEd community, with no clear heritage in earlier large GeoEd projects. The InTeGrate proposal described IPs as demonstrations of "department, institutional, and multi-campus approaches to curriculum and program structures that enroll general education, STEM and social science majors..."¹⁰ The urgency around creating such models was grounded in research showing that "...[l]asting change requires work at the department, program or institutional level (Seymour, 2001)."¹¹ As InTeGrate launched, the IP vision remained fuzzy to many of the leadership team members, and the picture only came into clearer focus over the course of months and even years. More so than any major element of InTeGrate, the IP model had to be designed, tested and refined from the ground up.¹²

As ultimately instantiated, an "InTeGrate Implementation Program" came to mean "an institution, or cluster of institutions, that applied for [and received] a grant to develop and evaluate programs demonstrating innovative ways of (1) increasing the diversity of students developing Earth literacy, and/or (2) teaching students to bring the geosciences to bear on societal issues."¹³ Each of the 16 IPs¹⁴ comprised a leadership team and affiliated faculty, who sought to use InTeGrate ideas and resources to affect change on their campuses or regions. IP teams were encouraged to build on the affordances and tackle the challenges that were important in their particular context, and to freely adapt InTeGrate resources in so doing. Four IPs were emplaced during InTeGrate's start-up phase,¹⁵ and the others were selected through a competitive proposal process during the latter half of the project.¹⁶

⁹ "Implementation program" is the label that was used throughout the project for efforts to affect change on the scale larger than a single course, funded by a sub-award, led by a faculty team, and leading to a web-published product. The leadership of these teams continue to use the term "Implementation Program" or the abbreviation "IP." However, on the InTeGrate website they are called "Program Models": <https://serc.carleton.edu/integrate/programs/implementation/index.html>. One way to reconcile these two terms is to consider that "Implementation Program" refers to the activity, and "program model" refers to the published product. In this report, Implementation Program (IP) will be used for both to minimize confusion.

¹⁰ InTeGrate proposal Project Summary.

¹¹ Proposal quote from InTeGrate proposal project description page 5. Cited reference: Seymour, E. (2001). "Tracking the process of change in U.S. undergraduate education in science, mathematics, engineering, and technology." *Science Education*, 86.

¹² There are many lessons to be learned from start up phase of the Implementation Program for anyone planning a similar program elsewhere, but these will not be explored in this report, which is focused on claims of impact and accomplishment. External evaluator Carol Baldassari delved into the workings and challenges of the first six IPs via interview, email and document review. Her observations and insights were used formatively to refine the IP program, and are recorded in an informal report: "Report on the Early Work of Six of InTeGrate's Implementation Programs." The most compelling finding from this work was the importance of institutional fit: the first six IPs all connected to and built on something (a program, a priority, a goal) that was already established at the host institution.

¹³ Orr, C. H., & McDaris, J. (2019). Supporting implementation of program-level changes to increase learning about Earth In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 69-90.

¹⁴ Program descriptions for the 16 IP programs can be accessed at: <https://serc.carleton.edu/integrate/programs/implementation/index.html>

¹⁵ The proposal described five IPs, which were to initiate this program element. IPs planned for the University of El Paso area and among a consortium of Washington State institutes of higher education proceeded more or less as

Each IP team was required to articulate program goals and develop and implement an evaluation plan to chart progress towards those goals. Program evaluation was an unfamiliar skill set for many of the teams, and InTeGrate devoted high-level talent¹⁷ to coaching the IP leadership through the process of developing the required evaluation programs. InTeGrate provided some tools, including the student assessments described above under Sub-Claim 1D and a faculty survey instrument. But because each IP had distinctive goals and program design, InTeGrate did not require the use of specific evaluation instruments. There was a trade-off between collecting a uniform and consistent dataset suitable for evaluation purposes across the entire InTeGrate archipelago, and collecting evaluation data more closely tailored to the individual context of each IP. There was a related tradeoff between telling the IPs how to do their evaluation and coaching them through the process of developing and implementing their own evaluation plan. InTeGrate opted for the unusual latter option, reasoning that faculty would be more likely to use the resultant data for program improvement and would tend to develop an evaluation mindset that they would carry forward after the IP ended.

Extracting generalizable lessons learned from such a diverse group of programs was a challenge. InTeGrate adopted a methodical synthesis process that SERC had developed for an earlier project.¹⁸ Five areas of overlapping interests were identified by the InTeGrate Leadership: Recruit and support diverse learners; Teach Earth across the curriculum; Prepare teachers to teach Earth Science; Support transitions to workforce, transfer and careers; Make and sustain change. Leaders from all the IPs were brought together for a two-day face-to-face workshop¹⁹ in December 2016, just after the deadline for IP teams to finish publishing their Program Profile. Working groups for each of the first four themes captured insights and examples into the Serckit content management system, and reviewed each others' working documents. The full group worked together on Theme 5: Make and Sustain Change.²⁰ These raw materials were then massaged by SERC staff and InTeGrate leadership into a set of published web pages: Synthesis of Lessons Learned.²¹

In addition, InTeGrate staff identified a suite of "Program Elements" that were used by various IPs to further their goals. The "Program Elements" showcased by each IP were highlighted on the landing page

planned, albeit more slowly than initially envisioned. IPs based at Stanford University and the Penn State system also developed, although in forms quite different from originally proposed. A fifth IP planned for James Madison University did not launch.

¹⁶ Calls for IP proposals were issued in Spring 2014, Fall 2014, and Spring 2015, in other words, during Project Years 3 and 4. The guidelines were narrowed for each successive call, so as to fill gaps in InTeGrate's portfolio. The proposal review team included members from the InTeGrate Advisory Board, the InTeGrate Leadership Team, and the leadership of the National Association of Geoscience Teachers (NAGT.) The proposals themselves are here: https://serc.carleton.edu/admin/submission_queue.php?form_id=2126 [Restricted access]

¹⁷ External evaluator Carol Baldassari, Assessment Team Chair David Steer, other Assessment Team members, Advisory Board member Judith Ramaley, and senior level SERC staff all worked extensively on building evaluative and program design capacity in the IPs. More detail in Orr & McDaris (2019). *op. cit.*

¹⁸ HHMI Capstone Institutions (2018). Supporting STEM Success in the Liberal Arts Context: <https://serc.carleton.edu/liberalarts/about/index.html>

¹⁹ Implementation Teams Workshop: <https://serc.carleton.edu/integrate/programs/implementation/2016synthesis/index.html>

²⁰ The "Make and Sustain Change" theme is one that SERC has been pursuing across multiple projects, using the variants of this crowd-sourced gather and synthesize technique. C. Manduca, personal communication, Sept. 2018. Other projects include Supporting STEM Success in a Liberal Arts Context (<https://serc.carleton.edu/liberalarts/change/index.html>); Network of STEM Education Centers (<https://serc.carleton.edu/StemEdCenters/toolkit/index.html>); and the NAGT Geoscience Education Researcher Community Toolbox (<https://nagt.org/nagt/geodresearch/toolbox/index.html>).

²¹ Synthesis of Lessons Learned: <https://serc.carleton.edu/integrate/programs/implementation/index.html#synthesis>

for that IP's program description, which then provided a link to a browse page²² for other IPs using that same program element (Exhibit III-1). Both the Program Elements browse functionality and the Lessons Learned Synthesis pages are structured in such a way that they should theoretically facilitate the effort of a potential reformer or innovator to identify and make use of commonalities with their own situation. A likely cognitive mechanism by which a potential reformer might spot ideas or strategies or structures in an IP that would be of potential use in his or her own institution is analogical mapping. Analogic mapping would identify parallels between the model situation (the IP, the source analog) and the situation at the reformers' institution (the target analog) that could be learned from and built upon. Cognitive research has shown that analogical mapping tends to be more powerful when two or more source analog instances or cases are available and when a term or label is used to reify the commonality or relationship.²³ Both the Program Elements browse function and the Lessons Learned Synthesis pages provide pointers to multiple examples of a common strategy and label that strategy with a distinctive term. However, no testing was done to determine how well these functions work in practice to enable transfer of the IP-derived models to new contexts.

Public documentation of the IP program includes individual IP website program profiles, lesson(s) learned syntheses, manuscripts about individual IPs, presentations about individual IPs, webinars, and an overview paper. In addition, the evaluation team had access to quarterly reports, structured reflections from team leads, structured interview with selected IP leaders by external evaluators, plus evaluator Kastens attended the IP Team Synthesis Workshop on Dec 7-8, 2016. Questions about IPs fall into three temporal/scale categories: (a) How much was accomplished within the IP institutions during the IP grant? (b) How enduring were the impacts within the IP institutions after the IP money ran out? (c) To what extent have other institutions used the IP as a model for their own reforms/ changes/improvements?

The InTeGrate proposal envisioned 26 Implementation Programs "across a diverse range of disciplines, institutions and networks."²⁴ Given the large amount of staff time and leadership team time needed to recruit, select, coach and monitor each IP, and the challenge of synthesizing lessons learned across such diverse program models, 26 IPs was not feasible; 16 was a major accomplishment. The proposed "diverse range of disciplines, institutions and networks" was achieved within the group of 16.

Sub-claim 2A: InTeGrate has increased the nation's capacity for preparing pre-service K-12 educators to teach about the Earth through undergraduate education of future teachers.

InTeGrate's contribution to K-12 education came through efforts to improve the Earth education of K-12 teachers during their undergraduate preparation. Within that undergrad context, InTeGrate emphasized two strategies: (a) helping Geo faculty adjust their Intro-level teaching to better align with the needs of future K-12 teachers, and (b) helping education faculty add more Earth Science content to their instruction.²⁵ Fortuitously, the 2012 advent of InTeGrate coincided with the publication of the

²² Implementation Programs > Program Elements:
<https://serc.carleton.edu/integrate/programs/implementation/components.html?>

²³ Gentner, D. (2010). Bootstrapping the mind: Analogical processes and symbol systems. *Cognitive Science*, 34(5), pp. 752-775. Gentner, D., & Colhoun, J. (2010). Analogical processes in human thinking and learning. In B. Glatzeder, V. Goel & A. v. Muller (Eds.), *On Thinking: Volume 2. Towards a Theory of Thinking*. Berlin: Springer-Verlag, pp. 35-48. See also: Kastens, K.A. (2011). Faculty professional development by means of case-based reasoning. *Earth & Mind: The Blog*. Online at: <https://serc.carleton.edu/earthandmind/posts/cbr.html>.

²⁴ InTeGrate proposal, project summary, page 7.

²⁵ Some of the faculty members who worked on InTeGrate's undergraduate materials for education of K-12 pre-service teachers also brought InTeGrate's ideas and materials to in-service teachers. However, those efforts were not part of the DUE-funded InTeGrate project, and thus will not be discussed in this report.

Framework for K-12 Education, followed shortly by the roll out of the Next Generation Science Standards (NGSS).²⁶ These documents devote 1/3 of their disciplinary attention to Earth & Space Science, and 1/3 of their Earth & Space Science attention to “ESS3: Earth and Human Activity.” The essential question in this part of the NGSS is “How do Earth’s processes and human activities affect each other?” a question that InTeGrate materials were well situated to address.

Gather, synthesize & disseminate best practices relevant to preparing future K-12 teachers

Through workshops, community contributions, Implementation Programs, and Leadership Team expertise, InTeGrate has gathered and synthesized information about preparing future teachers to teach about the Earth and sustainability. This information has been disseminated through the InTeGrate website²⁷ and through webinars²⁸ and workshops.²⁹

K-12 teachers learn much of their Earth Science content in Intro-level courses taught by geoscience faculty members, rather than in their education courses. However, most college geoscience faculty have had little guidance or instruction on the needs of future teachers. Earlier NSF-funded geoscience education projects recognized this disconnect,³⁰ and InTeGrate has continued the effort to help Geoscience faculty reach this important audience more effectively. The guidance provided is highly practical and written in a collegial voice that is accessible to a busy faculty member. Assuming little prior knowledge about America’s K-12 education system, InTeGrate’s teacher preparation materials begin with the fundamentals (e.g. “What is Teacher Preparation?” and “What are the Next Generation Science Standards?”) and offers concrete actions (e.g. offer a special lab session or discussion session for future teachers). All of the suggestions are fleshed out with Earth-specific examples, and some of them address Earth-specific challenges that are rarely covered in general teacher prep courses, such as teaching in the field (out in nature). There are also resource collections of courses, lessons, and essays contributed by members of the InTeGrate community and curated with respect to their utility for teaching about the Earth at the K-12 level.³¹

InTeGrate Leadership Team member Anne Egger spearheaded an effort to gather information about education-oriented students who enroll in Intro-level Geoscience courses (Egger et al, 2017).³² As many as 44% of Intro students were found to be potential future teachers, far outnumbering prospective Geoscience majors, and Egger makes the case that the content and pedagogy of such courses should attend more to their needs. Based on InTeGrate project-wide assessments, the future teachers have higher

²⁶ National Research Council (2012). *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*. Washington, DC: The National Academies Press. NGSS Lead States (2013). *Next generation science standards: For states, by states*. Washington, D.C.: National Academies Press.

²⁷ Prepare Future Teachers: <https://serc.carleton.edu/integrate/programs/teacherprep/index.html>

Implementation Programs > Build Connections to Strengthen K-12 Teaching:
<https://serc.carleton.edu/integrate/programs/implementation/teacherprep/index.html>

²⁸ E.g.: Webinar: Transforming Teacher Preparation to Teach for Sustainability:
https://serc.carleton.edu/integrate/workshops/webinars/2015_2016/teacher_prep/index.html#res

²⁹ e.g. Workshop: Connecting Earth Science and Sustainability to Teach the NGSS (August 1-3, 2018):
https://serc.carleton.edu/integrate/workshops/teach_ngss/index.html

³⁰ Earlier work on this challenge was done by the DLESE Community Services project in the early 2000’s, including a 2003 workshop on *Developing the Earth Science Teacher Workforce: The role of Geoscience departments and introductory courses* (<https://serc.carleton.edu/teacherprep/workshops/workshop03/index.html>) and associated website: *Preparing Teachers to Teach Earth Science* (<https://serc.carleton.edu/teacherprep/index.html>).

³¹ Workshop outcomes from Teaching the Methods of Geoscience workshop:
https://serc.carleton.edu/integrate/workshops/methods2012/workshop_outcomes.html

³² Egger, A., Kastens, K. A., & Turrin, M. (2017). Sustainability, the Next Generation Science Standards, and the Education of Future Teachers. *Journal of Geoscience Education*, 65, 168-184.

rates of sustainable behaviors than their non-education-oriented classmates, are more motivated by family and friends, are more likely to envision using their knowledge about sustainability in their careers—but have more limited understanding of key concepts such as systems thinking (Exhibit III-2).

Curriculum Materials developed specifically for K-12 Teacher Prep

Interdisciplinary teams with expertise in both geoscience and teacher prep have designed and tested InTeGrate materials explicitly for use in pre-service education courses for undergraduates (Exhibit III-3.)³³ There are three such modules, two of which are best suited for elementary education majors, and the third, for secondary education majors. All use the kinds of student-centered pedagogy that teachers will be expected to use in their future careers, and target the three dimensions of the NGSS (disciplinary core ideas, cross-cutting concepts, and science/engineering practices). Each uses as its content domain an aspect of the Earth system that is accessible in all geographic regions: water, soil, or weather/climate. InTeGrate's influence comes through strongly in the focus on geoscientists' ways of knowing, use of geoscience data, and connections to societal problems.

The teacher prep modules have achieved uptake well beyond the developer/tester group. The InTeGrate classroom usage database records between 40 and 110 enactments using each of the teacher prep modules. This is in the middle of the pack for usage of InTeGrate courses and modules (compare with II-9 in Claim 1 chapter).³⁴ Of the various teacher-education oriented web content served by InTeGrate, the classroom-ready curriculum modules have generated substantially more attention from web visitors than the more program-oriented pages, such as the Prepare Future Teachers page (Exhibit III-4, top panel.)

Enable Search and Browse by NGSS component

Beyond the modules explicitly targeted for pre-service teacher prep, teachers and teacher-educators have found many other resources and activities in InTeGrate's materials that are suitable for use in education programs that follow the Next Generation Science Standards. To facilitate use of InTeGrate by such users, a team of K-12 educators and teacher-educators coded each InTeGrate module and course for NGSS alignment.³⁵ Each module was coded by one person, reviewed by another team member, and the final coding for all materials was reviewed by an editor for consistency. The coding criterion was that an InTeGrate unit must “thoroughly and explicitly” address a component of the NGSS to be coded with it.

Now, when a potential user views the landing page for each unit of any InTeGrate course or module, the distinctive NGSS icon gives access to a pull down menu specifying which Science & Engineering Practices (SEP), which Cross Cutting Concepts (CCC), which Disciplinary Core Ideas (DCI) and which Performance Expectations (PE) align with that module. Conversely, if an educator wishes to design a lesson to meet a particular component of the NGSS, she can search and browse the InTeGrate collection for any specific CCC, SEP, DCI or PE.³⁶ The majority of the DCI and PE codes point to Earth & Space Science, but Life Sciences, Physical Sciences, and Engineering/Technology are also represented.

³³ See also webinar Transforming Teacher Preparation to Teach for Sustainability at: https://serc.carleton.edu/integrate/workshops/webinars/2015_2016/teacher_prep/index.html

³⁴ Data from Excel file classroomuse_2018_ks11.2.18.xlsx, provided by Kathryn Sheriff, SERC, November 2018.

³⁵ InTeGrate and NGSS > Our approach: https://serc.carleton.edu/integrate/teaching_materials/ngss/approach.html

³⁶ InTeGrate and NGSS > Search and browse by NGSS: https://serc.carleton.edu/integrate/teaching_materials/ngss/ngss_browse.html?q1=sercvocabs__319%3A1

A model for improving capacity for Earth teacher-prep across an entire state

The Washington State Implementation Program³⁷ laid the groundwork for a statewide improvement in preparing teachers for teaching Earth Science under the NGSS framework, and has provided a roadmap of how other NGSS-adopting states could do the same. The collaboration reached close to 100 faculty members at all of the institutions in Washington State involved in teacher-education, including those from two-year colleges, and also drew in the state Office of the Superintendent of Higher Education and other key stakeholders. InTeGrate funding supported three Saturday workshops across calendar year 2015: the first to identify strengths, consider drivers of change, and envision the STEM teacher of the future; the second to learn about innovative and successful STEM teacher preparation programs and begin the creation of a teacher preparation framework aligned with NGSS; and the third to cement the shared vision and organize for future action.³⁸ An essential aspect of their work was to situate teacher-prep programs as collaborators, rather than as competitors for students and dollars.

The Washington IP pulled together a proposal team, which wrote a successful proposal to NSF's IUSE program, which funded the NextGen-WA STEM Teacher Preparation Project, which launched in 2016. As documented on their project website,³⁹ NextGen-WA has assembled a collection of relevant resources and held capacity-building workshops around organizational change, diversity, and clinical practice. As of early 2019, no other states have picked up on the WA model of state-wide collaboration for STEM teacher preparation.⁴⁰

Models for incorporating more Earth Science content into pre-service science education courses

Two Implementation Programs had improving the Earth education of pre-service teachers as one of their main goals: Mercer University and Grand Valley State University. Together, they reached approximately 1300 prospective future teachers, through quite different programmatic models (Exhibit III-5).

The IP at Mercer University in Georgia was a collaboration between faculty in the school of liberal arts and professional studies (Penfield College) and the school of education (Tift College).⁴¹ Mercer serves non-traditional working adult students, who tend to be invested in the local community and to remain in the area upon graduation. Of the Mercer students who used InTeGrate materials during the IP program, 54% were African American and 85% were female.⁴² The IP team introduced InTeGrate units or modules into nine existing courses in science and education,⁴³ and into PD workshops for in-service teachers. The most distinctive feature of the Mercer IP was to leverage the strong local commitment and local knowledge of their student population by creating webquests around virtual field trips to

³⁷ Washington State: NextGen STEM Teacher Preparation:
<https://serc.carleton.edu/integrate/programs/implementation/program1/index.html>

³⁸ Washington State > Making Change Happen:
<https://serc.carleton.edu/integrate/programs/implementation/program1/change.html>

³⁹ Creating Next Generation STEM Teacher Preparation Programs: NextGen-WA:
https://serc.carleton.edu/nextgen_wa/index.html. See also Webinar Introduction and Overview of NextGen-WA at:
<https://serc.carleton.edu/integrate/programs/implementation/program1/nov2016webinar.html>.

⁴⁰ A. Egger, email communication, January 30, 2019.

⁴¹ Mercer University IP program page:
<https://serc.carleton.edu/integrate/programs/implementation/mercer/index.html>

⁴² Mercer Univ. IP > Improving Programs:
<https://serc.carleton.edu/integrate/programs/implementation/mercer/program.html>

⁴³ Mercer Univ. IP > Improving Teaching and Learning:
<https://serc.carleton.edu/integrate/programs/implementation/mercer/materials.html>

geologically-significant destinations in Georgia.⁴⁴ Based on data from the IAI and informal feedback from students, the IP team reports that use of the virtual field trips is increasing students' interest in sustainability and their motivation to create a sustainable society.⁴⁵

The IP team at Grand Valley State University and two feeder 2YC's designed a new program⁴⁶ and two new courses, aimed at preparing teachers to teach in a more NGSS-aligned format and to qualify for an Integrated Science teaching endorsement that is valued in Michigan's teaching job market. Earth Science, including elements of two InTeGrate modules, was coupled with Life Sciences in a redesigned pedagogy course.⁴⁷ The Grand Valley IP leadership team used their graduates' relatively low scores on the Earth Science component of the state credentialing exam to make the case for increasing the Earth Science component of the science coursework.

Sub-claim 2B: InTeGrate has created materials and models for infusing teaching about the Earth into humanities, social sciences, STEM disciplines outside of Geosciences, and interdisciplinary contexts.

Gather, synthesize & disseminate best practices relevant to interdisciplinary contexts

Through workshops, Advisory Board expertise, Implementation Program activities, and literature review, InTeGrate has gathered and synthesized information about interdisciplinary teaching and building interdisciplinary connections.⁴⁸ Suggested practices include:

- Identify points of intersection where important ideas from the two domains overlap, making sure that these are at the “trunk” or “core” of the two domains, rather than extra add-ons out at the peripheral “twigs.”
- Capitalize on the strengths of each discipline or domain: for example, engineering students in a collaborative team may be more facile with numbers while geoscience students know more about the context from which the numbers came.
- Position student work in a context that is meaningful to them, which is engaging and provides a model for how different groups collaborate in the real world to solve authentic problems.

⁴⁴ Virtual Field Trip to Providence Canyon, a group of deeply eroded sedimentary strata nicknamed the “Little Grand Canyon”: <https://webquestprovidenc Canyon.weebly.com/introduction.html>. Virtual Field trip to Arabia Mountain, a monadnock historically quarried for granite: <https://webquestarabiamountain.weebly.com>. The Providence Canyon trip was used as the study site for InTeGrate module: *A Growing Concern*; the Arabia Mountain trip was used in connection with the InTeGrate module *Humans' Dependence on Earth's Mineral Resources*. The motivation and methodology for creating the virtual field trips is discussed by Hall, J., L. Bush, and C. Stapleton (2017) *Virtual Vistas: Creating and Implementing Virtual Field Trips*, in the Proceedings for the Society for Information Technology and Teacher Education International Conference, Austin, TX. Downloaded 3 Sept 2018, from <https://serc.carleton.edu/integrate/programs/implementation/mercer/program.html>.

⁴⁵ Mercer Univ IP > Improving Programs:
<https://serc.carleton.edu/integrate/programs/implementation/mercer/program.html>

⁴⁶ Program Change Request: Integrated Secondary Science Education Major, Grand Valley State University:
https://d32ogoqmya1dw8.cloudfront.net/files/integrate/programs/implementation/program4/new_program_proposal_integrated.pdf

⁴⁷ Syllabus of Record for new course: “Earth and Life Sciences in Secondary Education” at Grand Valley State University:
https://d32ogoqmya1dw8.cloudfront.net/files/integrate/programs/implementation/program4/sci_450_syllabus_record.pdf

⁴⁸ Insights about Interdisciplinary teaching derived from InTeGrate workshops are summarized at:
https://serc.carleton.edu/integrate/teaching_materials/interdisciplinary.html. Insights from the IP program synthesis are at https://serc.carleton.edu/integrate/programs/implementation/across_curr/index.html. These, in turn, draw on earlier syntheses on the Pedagogy in Action site at <https://serc.carleton.edu/sp/library/interdisciplinary/index.html>.

- Start off small, as for example, with guest speakers.
- Team teaching. Unite faculty and staff with common interests.
- Design linked courses, in which cohorts of students take multiple coordinated courses, either during the same semester or sequentially.

Humanities & Interdisciplinary materials

InTeGrate teams have developed and tested materials for teaching about the Earth in humanities courses and teaching about the Earth in interdisciplinary contexts. As a non-negotiable guideline, the materials development rubric requires all materials developed and published through InTeGrate to “develop students’ ability to address interdisciplinary problems.” The rationale for this requirement and a synopsis of InTeGrate’s approach to this challenge are spelled out in Gosselin, Manduca, Bralower, and Egger (2019):⁴⁹ “Developing solutions to these grand challenges requires an interdisciplinary approach that demands scientific investigation of the interactions of the geological, biological, chemical, and physical environments, in combination with exploration of the human dimensions and societal institutions whose values underlie our currently unsustainable ways of living. ... [M]odules and courses... employ an interdisciplinary educational framework that engages students in ... problem solving that requires using the tools, approaches, and/or data from two or more disciplines in a coherently integrated way... Interdisciplinary strategies better prepare students to address complex environmental problems, as members of society and in their future careers, while engaging a larger and more diverse cross section of the student population in learning about the Earth...”

Above and beyond the overarching guideline, certain modules and courses were explicitly designed for use in departments outside of geosciences, or were optimized for use in interdisciplinary contexts.⁵⁰ These materials are shown in Exhibit III-6.

Attention to InTeGrate materials and ideas by instructors outside of Geosciences

Between September 2017 and November 2018, InTeGrate deployed a brief “pop-up survey,” which appeared when a user viewed their 6th InTeGrate web page during the survey’s deployment. Twenty-three percent of pop-up survey respondents had come via participation in an InTeGrate workshop or webinar, or other involvement in InTeGrate. The rest had come via web search (48%), colleague referral (16%), email, news link, or other publication (10%), or did not state an answer. The pop-up survey is the best available sampling that includes instructors who came to InTeGrate from “out there,” the vast population of higher education instructors who did not participate in an InTeGrate professional development event.

The pop-up survey asked the respondent for their role (e.g. course instructor), reason for coming to the site, how they found the site, and also recorded the URL of the site they had been viewing when they came to the site that triggered the popup. Relevant to this sub-claim, the pop-up survey also asked what the respondent teaches, offering a choice of geoscience (earth, environmental, etc.), several other sciences, mathematics, geography, social sciences, and “I do not teach.”⁵¹ The pop-up captured 1778

⁴⁹ Gosselin, D. C., Manduca, C., Bralower, T. J., & Egger, A.E. (2019). Preparing students to address societally-relevant challenges in the Geosciences: The InTeGrate approach. In D. C. Gosselin, A. E. Egger & J. J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp.3-24.

⁵⁰ Teaching for sustainability > InTeGrate Teaching Materials Development: https://serc.carleton.edu/integrate/teaching_materials/itg_materials_dev.html#other

⁵¹ This is not the same subdivision of fields of study as used in the InTeGrate Attitudinal Instrument (IAI), nor the same parenthetical clarification of the scope of “geosciences.” Geoscience Education Research would benefit from an agreement on bins for fields of study, scope of geosciences, and agreement on where “environmental science” fits

responses to this question.⁵² Results are shown in Exhibit III-7 (upper). A clear majority (63%) of respondents indicated that they teach geosciences, under a broad definition that includes “environment” as well as “Earth.” However, 15% teach another physical or life science (physics, chemistry or biology) and 7% teach a social science.

Another glimpse of InTeGrate’s reach outside of Geoscience departments comes from the database of InTeGrate participants. This dataset aggregates information from the various forms that participants in InTeGrate events (webinars, workshops, etc.) fill out as they register. The database includes 4,210 individual registrants; for 1,454 of these, discipline of current department is recorded.⁵³ The distribution of respondent’s current department is shown in Exhibit III-7 (lower). Slightly over half of respondents were associated with either a Geoscience or Environmental Science department (43% Geo plus 13% Env). Another quarter were associated with another science or engineering. The final quarter spanned the academic landscape, including individuals from criminal justice, library science, religion, and emergency/disaster management departments.

Although neither the participant database nor the pop-up survey dataset is a perfect measure of who is learning about or using InTeGrate materials, these two independent datasets each show more than a quarter of respondents as coming from outside the Earth and environmental sciences, supporting the claim that InTeGrate has reached outside traditional Earth-teaching venues.

Earth Education across the curriculum in Implementation Programs

Five Implementation Programs concentrated on extending learning about the Earth out of geosciences departments and across the curriculum into liberal arts or interdisciplinary contexts. The number of faculty, students, and courses reached by each of the liberal arts and interdisciplinary-focused IPs are shown in Exhibit III-8.

The IPs based at Wittenberg University and Gustavus Adolphus College were designed to broaden access to science by introducing geosciences across the liberal arts curriculum. *Wittenberg* introduced 8 different InTeGrate modules into existing courses in Biology, Business, Chemistry, Communications, Earth Science, Health Science, Physics, and Political Science and World Languages,⁵⁴ and developed sustainability materials for the First Year Seminar taken by all students.⁵⁵ They also leveraged out-of-classroom experiences such as visiting speakers, internships, service learning, and travel-abroad programs to ground sustainability literacy in real world contexts.

Gustavus Adolphus introduced teaching about climate change into an exceptionally wide range of courses,⁵⁶ using a model in which a climate-knowledgeable faculty member (“the developer”)

(inside geosciences or alongside geosciences). Similarly, geography is sometimes counted as a social science and sometimes as a geoscience.

⁵² All data in this paragraph and associated figure are from spreadsheet provided by Kathryn Sheriff, SERC, titled popup_results_9.17.18.xlsx, downloaded from https://serc.carleton.edu/integrate/workspace/notes_final_eval.html [Restricted access], October 29, 2018. Description of when the pop-up surveyed appeared (upon viewing 6th ITG web page) is from Sean Fox, email January 30, 2019.

⁵³ Data as of September 11, 2018. In spreadsheet md_demographics_modules.v2_KK, provided by K. Sheriff, SERC.

⁵⁴ Wittenburg IP > Improving Teaching & Learning > Courses and Materials: <https://serc.carleton.edu/integrate/programs/implementation/program3/materials.html>

⁵⁵ Wittenburg IP > Improving Teaching & Learning > First year curriculum: https://serc.carleton.edu/integrate/programs/implementation/program3/first_year.html

⁵⁶ Introduction to Neurosciences (Psychological Sciences & Neuroscience), Nordic Colonialisms (Scandinavian Studies), Personal Fitness (Health Exercise Science), Religion & Ecology (Religion), Vertebrate Biology (Biology), Nomadic Pastoralists of Asia and Africa (Sociology & Anthropology), Faith, Religion & Culture (Religion), from

collaborated closely with a non-science colleague who wished to add a climate element to his or her course (“the host”). Additional support was provided via teaching circles and individualized coaching by the IP leadership. The co-developed mini-modules were customized to the specific course and host, and drew only lightly on InTeGrate’s modules. The intent was that the module would be given a practice run in front of IP colleagues, then taught by the developer in the host’s class, then taught by the host with the developer present, then carried forward by the host alone; that last step, transfer of ownership for climate teaching to the non-science colleague, did not happen in all cases. In interviews by the IP Leadership following the first mini-module implementation, the faculty were quite thoughtful about how climate content and science’s ways of knowing fit into their particular context.⁵⁷ One year after the publication of the Implementation Program (Aug 2018), four of the ten IP-developed modules are still in use by the host faculty. Of the others, 4 are inactive because of faculty departure or retirement, and another is inactive because the course is no longer taught. The IP leadership sees this as evidence of “the need to ‘train in’ new faculty on existing modules, and have refresher/renewals.”⁵⁸

Three IPs aimed to position teaching about the Earth into interdisciplinary academic structures (courses or programs), as opposed to the Wittenburg/Gustavus approach of infusing Earth education into existing courses across multiple disciplines. *California State University at Chico IP*⁵⁹ used InTeGrate materials to add depth and cohesion to a “Sustainability Pathway” through the university’s General Education curriculum. A GenEd “pathway” at CSU-Chico includes lower division foundational courses plus one upper division course in each of Natural Sciences, Humanities, and Societal Institutions, all around a common theme. Eight different courses along the “pathway” adopted between one and seven InTeGrate modules.⁶⁰ Most of these courses are taught every semester and reach large numbers of students, so the CSU-Chico IP reached the largest number of students of any the IPs that came into InTeGrate via the mid-program proposal process (Exhibit III-8).

The Pennsylvania State University IP created six courses which together constitute the basis of new interdisciplinary certificate and minor degree programs in Earth Sustainability. Although they were developed through Penn State’s College of Earth and Mineral Sciences, they all have a strong policy component, which developers report has increased the relevance to students who are taking online courses while already in the workforce. They are designed to be taught through distance learning or in a hybrid format combining online and face-to-face elements, and so are discussed in detail under Sub-claim 2D (opportunities for students at institutions with no or limited geo faculty.)

The University of South Dakota IP⁶¹ used the local Missouri River as the common theme running through courses in biology, history, English, economics, education, anthropology, communications,

Gustavus Adolphus IP > Making Change Happen > Faculty Reflections & Stories:
<https://serc.carleton.edu/integrate/programs/implementation/program2/reflections.html>

⁵⁷ Gustavus Adolphus IP > Workspace > Interviews of Participating Faculty:
https://serc.carleton.edu/integrate/programs/implementation/program2/workspace/faculty_intervi.html (restricted access)

⁵⁸ Email to K. Kastens from Gustavus IP team leader Laura Triplett, Aug 27, 2018.

⁵⁹ CSU Chico Sustainability Program: <https://serc.carleton.edu/integrate/programs/implementation/chico/index.html>. Also, Teasdale, R., Hatfield, C., Clements, P., Altir, L., Hankins, D., & Willard, E. (2019). Modified use of InTeGrate curriculum in the Sustainability General Education Program at California State University, Chico. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp.277-296.

⁶⁰ CSU Chico IP > Improving Teaching & Learning > Courses & Materials:
<https://serc.carleton.edu/integrate/programs/implementation/chico/materials.html>

⁶¹ University of South Dakota—Sustainable Rivers: Integrating Earth Science and Sustainability across the curriculum: <https://serc.carleton.edu/integrate/programs/implementation/southdakota/index.html>

Native American studies, as well as Earth science. The IP leveraged the resources and personnel of the Missouri River Institute⁶² on campus, and the power of place-based pedagogy.

Infusing more Earth Systems into Biology Education: the QUBES Collaboration

“QUBES is a community of math and biology educators who share resources and methods for preparing students to use quantitative approaches to tackle real, complex, biological problems.”⁶³ QUBES accomplishes much of its work through Faculty Mentoring Networks (FMN), which are online groups, typically of 10-15 faculty members, who are focused on a specific topic or material, and meet regularly over a period of months. In 2015 through 2017, a group of ten life sciences faculty worked to adapt InTeGrate modules into their biology and environmental science classes.⁶⁴

QUBES participants were surveyed twice: two weeks after teaching (qualitative survey) and then upon completion of FMN activities (quantitative survey).⁶⁵ In their responses to the first survey, respondents were frank about the challenge of adapting the materials for life science, but also about the value of the supports provided: “In a biology class, these materials are not quite ‘turnkey.’ It will take time to adapt them and add in the ‘life,’ but the pedagogical structure that is built into the modules makes them a big hit in classrooms—so go for it!” On the second survey, when asked about the extent to which experience with the FMN had influenced their teaching in each of 13 different ways, respondents gave consistently highest scores (“true for me to a great extent”) to the following items: “manner in which I design/develop courses,” “content I use in my courses,” and “way in which I collaborate with others related to my teaching.”

Sub-claim 2C: InTeGrate has reached underrepresented minorities who might otherwise have had limited access to quality Earth education, and has built capacity to attract and support diverse students along their path towards geo-literacy and/or the geoscience workforce.

The opening paragraph of the InTeGrate proposal promised to “educate a diverse citizenry...including those who are historically underrepresented in the geosciences...”⁶⁶ As the project developed, InTeGrate defined diversity broadly, to include “ethnic and racial minorities, women, people with disabilities, veterans and active duty military personnel, people of low socioeconomic status, LGBTQ individuals, and other groups that are not represented in the geosciences in proportion to their abundance in society.”⁶⁷ InTeGrate’s approach was bidirectional and built on existing strengths and structures: (a) attract a greater diversity of students to venues where strong Earth-related education is already happening and support them when they got there, and (b) bring strong and more relevant Earth-related education to places where underrepresented minorities already are concentrated.

⁶² Missouri River Institute: <https://www.usd.edu/missouri-river-institute>. However, note that their website makes no mention of the InTeGrate-funded Sustainable Rivers program.

⁶³ QUBES > About Us: <http://qubeshub.org>

⁶⁴ InTeGrate QUBES Faculty Mentoring Network: https://serc.carleton.edu/integrate/teaching_materials/qubes.html

⁶⁵ QUBES InTeGrate FMN Qualitative data summary:

https://d32ogoqmya1dw8.cloudfront.net/files/integrate/teaching_materials/qualitative_results_summary.pdf.

QUBES FMN Survey 2 Quantitative data summary:

https://d32ogoqmya1dw8.cloudfront.net/files/integrate/teaching_materials/survey_2_quantitative_results.pdf.

⁶⁶ InTeGrate proposal, Project summary.

⁶⁷ Increase the Diversity of your Graduates: <https://serc.carleton.edu/integrate/programs/diversity/index.html>

As articulated by Gosselin et al (2019),⁶⁸ strategies to attract, retain, and support students in existing Earth-learning venues included using pedagogical approaches that support broad student success, integrating societal issues with geoscience content, and attending to students' sense of belonging, motivation to succeed, mentoring and advising. Strategies to build capacity for quality Earth education in minority-rich venues included ensuring that MSI and 2YC expertise was at the table in the Leadership Team and Advisory Board, designing workshop topics around topics that would attract allies from among faculty who teach students from underrepresented communities,⁶⁹ and establishing Implementation Programs at institutions with diverse student bodies.

Building diversity & inclusion expertise in the Leadership Team

In terms of race and ethnicity, Geoscience has one of the least diverse workforces and least diverse student bodies of any of the STEM disciplines.⁷⁰ From Day 1, InTeGrate leadership was well aware of this demographic data, and convinced that tackling Earth's environmental problems would require all human beings, of all races and ethnicities, to become part of the solution. Co-PI Diane Doser, of the 83% Hispanic-enrollment University of Texas at El Paso,⁷¹ was a consistent voice for processes and policies that would benefit students from under-represented minorities, while Leadership Team member Elizabeth Nagy-Shadman, of Pasadena City College, spoke up for students and faculty at 2YC's.

And yet, in its early years, InTeGrate struggled to gain traction on the challenges of broadening access to learning about the Earth and attracting and supporting diverse students to Earth-related majors. A face-to-face 2YC and Diversity Planning Meeting⁷² was held early in project year 1, less than a month after the Leadership Team met each other for the first time. That meeting did not yield the hoped-for diversity-focused Implementation Program.⁷³ The role of Diversity Coordinator was established, and two short-lived incumbents cycled through the role. A 2014 workshop gathered insights about challenges and best practices,⁷⁴ but follow-up discussions among the leadership did not gel into action.⁷⁵ The challenge

⁶⁸ Gosselin, D. C., Manduca, C., Bralower, T. J. & Egger, A.E. (2019). Preparing students to address societally-relevant challenges in the Geosciences: The InTeGrate approach. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 3-24.

⁶⁹ The prototype for this strategy was the workshop on Teaching Environmental Justice: Interdisciplinary Approaches, in project year 2 (April 2018): <https://serc.carleton.edu/integrate/workshops/envirojustice2013/index.html>. This workshop catalyzed the module on Environmental Justice and Freshwater Resources, which went on to become one of the most-used modules, both at MSI and non-MSI institutions (see Exhibit III-14).

⁷⁰ Czujko, R., & M., H. (2003). Good news and bad news: Diversity data in the geosciences. *Geotimes*, 9, pp. 20-22. Mosher, S., Bralower, T., Huntoon, J., Lea, P., McConnell, D., Miller, K., Ryan, J., Summa, L., and Villalobos, J. (2014). Summary report for summit on future of undergraduate geoscience education. Available at http://www.jsg.utexas.edu/events/files/Future_Undergrad_Geoscience_Summit_report.pdf. Wilson, C. (2016). Status of the Geosciences Workforce (p. 131). Alexandria, VA: American Geosciences Institute. Bernard, R. E., & Cooperdock, E. H. G. (2018). No progress on diversity in 40 years. *Nature Geoscience*, 11, pp. 292-295.

⁷¹ 2017-2018 Hispanic-serving institutions: <https://www.hacu.net/images/hacu/OPAI/UPDATED%202017-2018%20HSI%20List.pdf>

⁷² Leadership Team Workshop > 2YC and Diversity February Planning Meetings: <https://serc.carleton.edu/integrate/meetings/2yc2012/planworkspace/index.html> [Restricted access]

⁷³ C. Manduca, personal communication, Sept. 2018. Also: 2YC and Diversity February [2012] Planning Meetings: <https://serc.carleton.edu/integrate/meetings/2yc2012/planworkspace/index.html> [Restricted access]

⁷⁴ Broadening Access to the Earth and Environmental Sciences: Increasing the Diversity of Undergraduate Students Learning about the Earth > Workshop Synthesis: https://serc.carleton.edu/integrate/workshops/broaden_access/synthesis.html

of broadening participation was discussed at leadership meeting after leadership meeting, and yet little changed.⁷⁶ At the time of the mid-project evaluation report (Fall 2014), there was little concrete progress on diversity to report,⁷⁷ although not from lack of attention or concern. Project leadership and staff continued to scan the landscape, looking for successful models, allies, champions and attachment points for diversity in geoscience education.⁷⁸

A turning point came in project year 4 (2015), when Dr. Felicia Davis (Exhibit III-9) was recruited to join the Leadership Team. Davis brought a robust network of environmentally-oriented contacts among Historically Black Colleges and Universities from her work on the Green Building Initiative at Clark Atlanta University Center and related efforts to foster sustainability on historically black, Hispanic-serving and tribal colleges and universities.⁷⁹ The HBCU Geoscience Working Group (covered in more detail in Claim 3) was founded at the 2016 Earth Educators' Rendezvous (University of Wisconsin at Madison). From that beginning, the HBCU working group was active at the 2017, 2018, and 2019 Rendezvous, recruited leadership for two Implementation Programs (Clafin and Savannah State), sponsored three face to face InTeGrate workshops, began a research program to collect and analyze data from students in InTeGrate-influenced courses at HBCU's, and wrote a successful NSF GeoPaths proposal. As of 2018, the HBCU Working Group had representatives from 24 institutions across ten states.⁸⁰ This flourishing of diversity-oriented activity took off only in the latter half of the project and has not had the run-time of other parts of the InTeGrate project.

Gather, synthesize & disseminate data, information & best practices relevant to diversity

InTeGrate has gathered, synthesized and disseminated information that is relevant to: (a) attracting and supporting underrepresented minorities in places where the Earth is being taught, and (b) increasing and strengthening teaching about the Earth in places where large numbers of underrepresented minorities are already seeking educational opportunities. This information-gathering work has been done through a combination of literature review, workshops⁸¹ (see also Claim 3, HBCU section), sessions at the Earth Educators' Rendezvous, and insights from Leadership Team and Advisory Team members. Dissemination has been through workshops, journal articles, webinars, web pages, and Rendezvous sessions. Of the two plenary speaking slots at the Earth Educators' Rendezvous, at least one each year has been invested in a high-profile speaker in the area of broadening participation, diversity, environmental justice or culturally appropriate pedagogy (Exhibit III-10). Symbolic of the recognition that diversity in geoscience education remains a work in progress, the very last face-to-face workshop

⁷⁵ Leadership Team Workspace > Diversity Plan: *
https://serc.carleton.edu/integrate/workspace/diversity_plan.html [Restricted access]

⁷⁶ Leadership Team Workspace > March 2013 Face-to-face meeting:
https://serc.carleton.edu/integrate/workspace/spring_2013_fac.html [Restricted access]. Leadership Team Workspace > July 2014 Face-to-face meeting: https://serc.carleton.edu/integrate/workspace/july_2014_face-.html [Restricted access]

⁷⁷ Kastens, K. A., Baldassari, C., & DeLisi, J. (2014). InTeGrate: Interdisciplinary Teaching of Geosciences for a Sustainable Future: Mid-Project Evaluation Report.
https://serc.carleton.edu/admin/private_download.php?file_id=75442 [Restricted access]

⁷⁸ Watson Nelson, Teana, (2013). InTeGrate Diversity Summary. Unpublished document provided by Ellen Iverson, SERC.

⁷⁹ Felicia Davis biographical sketch: http://www.intentionalendowments.org/felicia_davis.

⁸⁰ Archer, R., Davis, F., Ebanks, S. C., & Gragg, R. D. S., III. (2019). HBCU's broadening participation in Geosciences (a journey through InTeGrate). In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 361-378. See especially Table 1.

⁸¹ Workshops at which expertise relative to diversity has been gathered are listed on:
<https://serc.carleton.edu/integrate/programs/diversity/index.html>

funded by InTeGrate, in April of 2019, deep into project year 8, was on “Diversity, Equity, and Inclusion in the Earth and Environmental Sciences: Supporting the Success of All Students.”⁸²

An early product of gathering and synthesizing work was a compilation and analysis of Earth-related education occurring at Minority Serving Institutions (MSI’s) (McDaris et al, 2017),⁸³ based on a systematic analysis of websites at 499 institutions officially recognized as Historically Black Colleges and Universities (HBCU), Hispanic-Serving Institutions (HSI), or Tribal Colleges and Universities (TCU). The major finding from this analysis is that nearly one third of MSI’s offer one or more degree programs that require students to take several courses focused on physical aspects of the Earth system and their interactions. However, most of these Earth-education opportunities are not in academic units labeled as Geology, Geosciences or Environmental Sciences. Many of them are in interdisciplinary units, such as Natural Science, or Geography, Life & Physical Sciences. From the viewpoint of the InTeGrate leadership, this analysis brought forward the existence of previously unsuspected collaboration opportunities, including in programs that were already committed to teaching about the Earth in an interdisciplinary context.

A second product from the gathering and synthesizing work was an articulation of best practices for attracting and supporting underrepresented minorities in geoscience education programs, summarized in Exhibit III-11. The ideas emerging from the gathering/synthesizing effort were disseminated through a paper in the *Journal of Geoscience Education* and a substantial area of the InTeGrate website.⁸⁴ Strategies and approaches were gathered under the themes of “Attract Diverse Students to STEM,” “Support the Whole Student,” and “Prepare Students for Careers.” InTeGrate’s diversity approach and materials have been influenced by the Jolly et al. (2004) model on supporting the whole student.⁸⁵ Jolly et al. make the case that three elements must be in place to ensure students’ success, and that they are interdependent: (a) Engagement: Students must be in engaged with school in general and science- or quantitative-oriented topics in specific, (b) Capacity: The learned skills and knowledge needed for science, and (c) Continuity: A clear pathway forward without insurmountable obstacles, and including access to appropriate courses and good teachers.

One distinctive aspect of the InTeGrate-provided materials on diversity is that they are presented in a format of “news-you-can-use” for Geoscience departments (“Increase the Diversity of Your Graduates”), positioned as advice for fixing a local problem rather than a national problem. Individual faculty members and departments may regret the national problem, but not see it as their responsibility to fix.

⁸² April 2019 diversity workshop website:

https://serc.carleton.edu/integrate/workshops/twp_support_students/index.html

⁸³ McDaris, J., Manduca, C. A., Iverson, E., & Orr, C. H. (2017). Looking in the right places: Minority-serving institutions as sources of diverse Earth Science learners. *Journal of Geoscience Education*, 65(4), pp. 407-415.

⁸⁴ *ibid.* (McDaris et al., 2017).

McDaris, J., Iverson, E., Manduca, C., & Orr, C. H. (2019). Teach the Earth: Making the Connection between research and practice in broadening participation. (unpublished information used with permission, email from J. McDaris, Nov 20, 2018.)

General insights from across InTeGrate are at: *Increase the Diversity of your Graduates: Attracting Supporting, and Preparing Minority Students in Geosciences and STEM Disciplines*,

<https://serc.carleton.edu/integrate/programs/diversity/index.html>

Insights specifically from Implementation Programs are at:

https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/index.html

⁸⁵ What does it Mean to Support the Whole Student?:

https://serc.carleton.edu/integrate/programs/diversity/what_support.html; Jolly, E. J., Campbell, P. B., & Perlman, L. (2004). Engagement, Capacity and Continuity: A trilogy for student success. A report commissioned by the GE Foundation.

The local problem of diversity among their own graduates may feel more like a problem they can and should tackle.

A second distinctive aspect of InTeGrate's diversity materials is that they are supported by richly-detailed descriptions of examples of the strategies in action at U.S. colleges and universities, told in their own words by faculty who participated in InTeGrate programs. "Instructor Stories"⁸⁶ from individual faculty, "Program Descriptions" from Implementation Programs,⁸⁷ and Lessons Learned synthesized across IPs⁸⁸ have some evaluative value in that they document that individuals and institutions took substantial steps to respond to the needs of diverse student bodies and that in the professional opinion of the writers, these steps have been effective. InTeGrate collected little to no quantitative data to test or support the recommended diversity strategies, relying on existing education research from other STEM fields and the professional judgment of the peers who wrote the Instructor Stories and IP Program Descriptions.

A final overarching attribute of InTeGrate's diversity materials is that many of the strategies that are offered to improve geoscience programs for underrepresented minorities are likely to improve geoscience programs for all students, for example: "Build a sense of community," and "Understand the needs of the workforce." Of course, improving programs for all students is unquestionably good. But it remains to be seen whether these strategies will narrow the gap between minority and non-minority students (as opposed to the different goal of raising education quality for all.)

It has been hard to gauge the impact of the "Increase Diversity" area of the InTeGrate website. Certainly, the Implementation Programs that focused on broadening access drew on the material. The front page of the web section on "Increasing the diversity of your graduates" has attracted 2452 page views and 1066 visitors, approximately as many as a moderately well-used curriculum module (Exhibit III-4.) The lessons learned from InTeGrate's diversity work have also been incorporated into a new theme in the Traveling Workshop Program: Supporting the Success of *All* Students.⁸⁹

Diversity among InTeGrate Materials Developers

Materials developers were an influential population within the InTeGrate community, in that they shaped the instructional materials that embody and carry forth into the classroom InTeGrate's priorities about what should be learned and how it should be taught. Faculty members of any personal background are capable of creating bias-free and culturally sensitive instructional materials. That said, there is value in having materials developers who bring a variety of experiences to the development process. As a proxy for diversity of experiences, the evaluators looked at how many developers were members of

⁸⁶ All faculty involved as materials developers, and many faculty in Implementation Programs, created "Instructor Stories," which are gathered at: https://serc.carleton.edu/integrate/teaching_materials/community_use/instructor_stor.html. Two examples of Instructor Stories that feature use of InTeGrate materials to reach underrepresented minorities or foreground issues of interest to minority communities: Marshall Shepherd, adding urban hydrology into an Applied Climatology course at the University of Georgia (https://serc.carleton.edu/integrate/teaching_materials/water_cities/shepherd_story.html). Benjamin Cuker, teaching about renewable energy and environmental sustainability at a comprehensive historically black university (https://serc.carleton.edu/integrate/teaching_materials/energy_sustain/cuker_story.html).

⁸⁷ Implementation Program Descriptions: <https://serc.carleton.edu/integrate/programs/implementation/index.html>

⁸⁸ Lessons Learned were synthesized across all IPs by a process described above in "About Implementation Programs." One of the six themes was "Attract and Support Diverse Learners." These insights were disseminated here: <https://serc.carleton.edu/integrate/programs/implementation/index.html#synthesis>

⁸⁹ The Traveling Workshop Program: Supporting Success of *All* Students theme: https://nagt.org/nagt/profdev/twp/supporting_all_students.html. The Traveling Workshop Program is further discussed in Claim 3.

groups that are underrepresented in science⁹⁰ and developers who currently teach at a Minority Serving Institution⁹¹ (Exhibit III-12). Of the 110 materials developers for which there is information, 10 are members of URM's and 11 teach at MSI's, with 7 overlapping between those two groups. Ninety-seven developers (88%) are neither members of URM groups nor do they teach at MSI's. This is a much whiter group than the students they were teaching.⁹² InTeGrate's leadership team did make concerted efforts to recruit Materials Developers of color and Materials Developers who have experience teaching in settings where URM students are abundant, through the HBCU working group, targeted workshops, and coaching of Materials Development proposal teams with promising but unpolished proposals. These efforts did *not* result in an upward trend over time (Exhibit III-12 lower) until the very end of the MD process, when the HBCU Working Group assembled one final team of Materials Developers around the topic of urban agriculture, urban food supply, and the Food-Energy-Water Nexus.⁹³

The InTeGrate proposal stated that “No fewer than 25 of the 150 positions on development teams will be filled by faculty from Two Year Colleges (2YC's) and Minority Serving Institutions (MSI's), including Historically Black Colleges and Universities (HBCUs) and Tribal Colleges and Universities (TCU's).”⁹⁴ Twenty-five out of 150 would have been 16%; and the actual fraction achieved was 22 out of 110, or 20%⁹⁵.

Participation in InTeGrate workshops by Faculty of Color

Participants in SERC-sponsored workshops (although not webinars) are asked for a variety of demographic information. Exhibit III-13 shows the numbers and percentages of workshop attendees⁹⁶ who reported being members of minorities under-represented in geosciences (URM's).⁹⁷ Numbers and percentages were low in the first five years of the project. In project year 6 (academic year 2016-2017), there was a step up in both numbers and percentages. That year, two workshops were held at HBCU's and co-convened by members of the HBCU working group to target topics of importance to URM's.⁹⁸

⁹⁰ Groups considered to be underrepresented in science are Black/African-American, Native American, Pacific Islander, and Hispanic/Latinx (can be of any race). Asian/Asian-Americans are not considered to be underrepresented in science.

⁹¹ United States Department of Education, Lists of postsecondary institutions enrolling populations with significant percentages of undergraduate minority students. Available at <https://www2.ed.gov/about/offices/list/ocr/edlite-minorityinst.html>

⁹² Demographics of students for whom pre- and post-instruction IAI data were collected (mostly students in the pilot tests of new InTeGrate materials) are given in Exhibit 7 of Kastens, K., Mara, V., & Turrin, M. (2018). InTeGrate Evaluation Report: IAI responses spanning the entire InTeGrate project (2012-2016). Of the 2896 students in that dataset, 669 (23%) report being Hispanic/Latinx (of any race). A further 315 (11%) did not report being Hispanic/Latinx but did report being members of a URM racial group (American Indian/Native American, Black/African-American, Alaskan Native, or Pacific Islander).

⁹³ The module developed by the development team emerging from the HBCU Working Group is *Food as the Foundation for Healthy Communities*: https://serc.carleton.edu/integrate/teaching_materials/food_energy_water/index.html

⁹⁴ InTeGrate proposal Project Description, page 3.

⁹⁵ Data from spreadsheet “md_demographics_modules.-MZB6Nov2019.xlsx” [Restricted access], from Monia Bruckner of SERC 7 November 2019.

⁹⁶ Data from spreadsheet “Sep 2018 workshop demographics_11.26ks.xlsx,” received from Kathryn Sheriff of SERC 10 December 2018.

⁹⁷ These numbers include free-standing workshops, plus InTeGrate-sponsored workshops within the Earth Educators' Rendezvous. General attendance at the EER is not counted, as that became an NAGT event rather than an InTeGrate event early in the project.

⁹⁸ Strengthening Geoscience Competency for HBCU Pre-service Teachers workshop, Feb 2016, Tennessee State University: https://serc.carleton.edu/integrate/workshops/hbcu_teacher/index.html. Pan-African approaches to

Comparing numbers of URM's per year with number of workshops per year⁹⁹ shows that, in the first four years of the project, average URM participation per workshop was on the order of 2 or 3 (probably not a critical mass), while in the later years, it was on the order of 6-10 (quite possibly a critical mass—although not evenly spread among events).

Uptake of InTeGrate materials at MSI's and 2YC's

Through a variety of forms and surveys,¹⁰⁰ InTeGrate asks instructors who use InTeGrate instructional materials where they teach, what materials they use, and how many students they are teaching or expect to be teaching. This number is surely an undercount, since some instructors would not have encountered a survey or form or would not have returned it. These surveys and forms do not ask about instructor demographics. However, from the institution name, it is possible to classify the institution type and thus learn about InTeGrate's reach into institution types that tend to have a higher fraction of first generation college students, low SES students, and racial/ethnic groups underrepresented in STEM. Exhibit III-14 (upper) summarizes how many course enactments (one course taught by one individual for one term) were taught at MSI's and 2YC's, how many such institutions and instructors were reached, and how many students had been taught or were scheduled to be taught.¹⁰¹ InTeGrate materials were used in 38 MSI's and 137 2YC's. Ninety-one different instructors at MSI's and 196 instructors at 2YC's are on record as having taught with InTeGrate materials.

The database also records which InTeGrate module or course was used in each enactment. Exhibit III-14 (lower) shows the most frequently used modules at all institutions, at MSI's and at 2YC's. The three lists are almost identical, although there is some shuffling of order. Environmental Justice and Freshwater Resources,¹⁰² which explicitly targeted issues of concerns to communities of color, is #2 on the MSI list—but it is also #4 on the list for all institution types. Faculty voting through their choice of modules to teach are telling us that the same InTeGrate modules are useful across a variety of institution types.

Implementation Programs striving to Broaden Participation in Geoscience

InTeGrate's IP effort invested heavily in broadening participation. Of the 16 IPs, ten had Broadening Participation as one of their major stated goals or foci (Exhibit III-15). Of the ten, two were HBCUs (Claflin Univ. and Savannah State Univ.) and three were Hispanic-serving institutions (Cal State Chico, University of Illinois at Chicago, and the University of Texas at El Paso). This focus was intentional: whereas the first and 2nd call for proposals (March 2014 and January 2015) under the IP program encouraged proposals that addressed eight varied needs or goals, the third and final call (June 2015) narrowed down the range of encouraged goals to more strongly foreground increasing the enrollment and graduation of students from groups underrepresented in the geosciences¹⁰³ (Exhibit III-16). The team

Teaching Geoscience, May 2017, Moorehouse College: <https://serc.carleton.edu/integrate/workshops/african-education/index.html>. The third workshop sponsored by the HBCU working group was the following Fall, Putting Sustainability into Action, Oct 2017, Florida A&M University: <https://serc.carleton.edu/integrate/workshops/sustainability-action/index.html>

⁹⁹ Number of tallied events per year were: 2011-2012: 4; 2012-2013: 4; 2013-2014: 4; 2015-2016: 12; 2016-2017: 12; 2017-2018: 2. This includes workshops, but not webinars, and includes InTeGrate-sponsored workshops within the Earth Educators' Rendezvous.

¹⁰⁰ Details on data sources for classroom use data are at the beginning of Sub-Claim 2E.

¹⁰¹ Data from Excel file classroomuse_2018_ks11.2.18.xlsx, from Kathryn Sheriff, SERC, 2 November 2018.

¹⁰² Environmental Justice and Freshwater Resources: https://serc.carleton.edu/integrate/teaching_materials/freshwater/index.html

¹⁰³ Call for Proposals for Implementation Programs with March 28, 2014 (Project Yr 3) deadline: https://serc.carleton.edu/integrate/participate/ip_call.html (page no longer active). Call for January 30, 2015 (Project Yr 4) deadline: https://serc.carleton.edu/integrate/participate/ip_call_f2014.html (page no longer active).

judging the IP proposals had expertise in diversity and inclusion and included this as a factor in their deliberations. Coaching was made available to help IP proposal teams that were strong on broadening participation in strengthening other aspects of their plan.

HBCU's: The Savannah State IP¹⁰⁴ leveraged its position along an extensive salt marsh estuarine system to bring together elements from multiple departments around the themes of environmental justice and coastal hazards. Elements from the ITG Coastal Processes, Hazards, and Society course were infused into 9 courses in departments ranging from Africana Studies to Marine Science, which were then woven into a certificate program in Coastal Hazards and Risk Management. The certificate program includes a capstone project and a stronger service learning component than in the original materials. Savannah State was the only IP to earn a second round of InTeGrate funding, and was the catalyzing institution for the HBCU working group's successful NSF GeoPaths proposal. Claflin University's IP¹⁰⁵ built on an existing campus Sustainability Initiative and began by infusing InTeGrate materials from the Map your Hazards module into eight natural science and social science courses, with mixed results. At the end of the IP phase, the leadership moved in an unanticipated direction, shifting the hazards-related instruction outside of the formal curriculum into an 8-hour certificate course in "Awareness and education for community natural disaster mitigation and preparedness." Their goal is to incorporate this InTeGrate-influenced content into the Freshman College, thus reaching all students with content of immediate and practical value in a region that has suffered from ice storms, flash floods, and hurricanes in recent years. Both of these HBCU-based IPs seem to have worked with the grain of their institutions and infused ITG content into their students' experiences in a way that has strong potential to persist. Both also benefited from and contributed to the HBCU working group.

HSI's: Cal State Chico was discussed above as a successful example of using InTeGrate materials in an interdisciplinary context, by building purposeful connections among the courses along the university's General Education Sustainability Pathway. The El Paso Higher Education Community IP served a community which is >80% Hispanic.¹⁰⁶ Geology faculty at the El Paso branch of the University of Texas, area community colleges, and early college high schools collaborated to create a strong pathway for underrepresented minorities into Earth Science degrees and courses. UTEP was the first launched, and thus the longest running, of the InTeGrate IPs, with first materials adoptions in 2013 (project year 2). The leadership of this IP provided strong and persistent support and encouragement to their colleagues, and their careful documentation of this protracted process across multiple years shows just how hard it can be for faculty to overcome obstacles that stand in the way of adopting new and different curriculum and teaching practices. They now have a core group of approximately 12 full-time and adjunct instructors

Call for June 30, 2015 (Project Yr 4) deadline: https://serc.carleton.edu/integrate/participate/ip_call_S2015.html (page no longer active). Deadline of the third and final IP call was ~18 months before the scheduled end of the 5 year grant. Which IP proposal came under which solicitation can be found at https://serc.carleton.edu/admin/submission_queue.php?form_id=2126 [Restricted access]

¹⁰⁴ Savannah State University: Collaborate to heighten awareness, rejuvenate, and train: CHARTing a course to bring environmental justice to the coast:

<https://serc.carleton.edu/integrate/programs/implementation/savannah/index.html>. Also Archer, R., Davis, F., Ebanks, S. C., & Gragg, R. D. S., III. (2019). HBCU's broadening participation in Geosciences (a journey through InTeGrate). In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp.361-378.

¹⁰⁵ Claflin University Program Model—CU InTeGrated:

<https://serc.carleton.edu/integrate/programs/implementation/claflin/index.html>

¹⁰⁶ University of Texas El Paso—Broadening access to the Earth Sciences across the El Paso Higher Education Community: <https://serc.carleton.edu/integrate/programs/implementation/program7/index.html>. Also, Doser, D., & Villalobos, J. (2019). Use of InTeGrate materials to engage instructors and encourage curriculum change in the El Paso Higher Education Community. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 297-328.

who use the materials each year, reaching about 400 students per year. This same group has become heavily involved in other activities that attract students into the geoscience transfer pathway and career pipeline, such as student research and service learning projects.¹⁰⁷

Non-MSI institutions: Five IPs not located at MSI's stated that broadening participation of underrepresented students learning about the Earth was one of their goals. The IPs at Grand Valley State and Mercer University were discussed above under Models for incorporating more Earth Science content into pre-service teacher education. Stanford University's IP is discussed below, under Sub-claim 2-D, "creating opportunities at institutions with no geo department or limited geo faculty." Among the IPs based at non-MSI institutions, the University of Northern Colorado and Middle Tennessee State University were notable for placing their efforts to increase the diversity of students learning about the Earth at the forefront of their efforts. In hopes of attracting more students and more diverse students to become Earth Science majors, the University of Northern Colorado¹⁰⁸ worked with eight local K-12 schools and 2YCs, offering field trips and school visits by university faculty. They doubled the number of students admitted to the major from 30 to 60, and developed articulation agreements with two local 2YCs. They wove more societally-relevant components throughout numerous Intro and upper division courses, and supported faculty in attracting and engaging diverse students through a campus workshop on "Building Diversity Awareness to Promote Student Success."¹⁰⁹ One reason that the UNC IP was able to accomplish so much so quickly was that their leader had been a developer on one of the first InTeGrate curriculum modules and been leading and participating in workshops in the SERC/InTeGrate model for more than a decade.¹¹⁰

Although attracting and retaining a more diverse group of students into majors programs and Earth-related courses for non-majors was a goal for many IPs, no IP presented data on student demographics before and after their intervention. The run time for most of the IP programs was quite short, and so this would have been a difficult outcome to document.

Shifting the GeoEd Community's Theory of Change around Diversity and Inclusion

Geoscience educators, as individuals and as a community, have been working on increasing the diversity of students who study and major in geosciences for decades. Two basic goals have remained essentially unchanged: "to increase participation in geoscience education and research by members of groups that have traditionally been underrepresented in geoscience disciplines," and "to enhance the understanding of the geosciences and their contribution to modern society by a broad and diverse segment of the population."¹¹¹

To this early formulation has been added a third goal: to contribute to national and global environmental sustainability by ensuring that all inhabitants of the planet have sufficient understanding of Earth system processes to be able to make decisions in their personal and professional lives that advance environmental sustainability and environmental justice.¹¹² Many programs, both NSF-funded and

¹⁰⁷ Doser & Villalobos (2019), *op cit*.

¹⁰⁸ University of Northern Colorado—Inviting diverse students to sustain their future: <https://serc.carleton.edu/integrate/programs/implementation/northerncolorado/index.html>

¹⁰⁹ U of Northern Colorado IP > Improving Teaching & Learning > Workshop: Diversity Awareness Training: <https://serc.carleton.edu/integrate/programs/implementation/northerncolorado/workshop2.html>

¹¹⁰ SERC Community Member Profiles: Cindy Shellito: <https://serc.carleton.edu/person/2054.html>

¹¹¹ National Science Foundation Geosciences Directorate: Strategy for Developing a Program for Opportunities for Enhancing Diversity in the Geosciences (NSF 01-53): https://nsf.gov/geo/diversity/geo_diversity_strategy_document_jan_01.jsp

¹¹² "Why focus on Diversity?" in Gosselin, D. C., Manduca, C., & Bralower, T. J. (2019). Preparing students to address societally-relevant challenges in the Geosciences: The InTeGrate approach. In D. C. Gosselin, A. E. Egger

otherwise, have contributed to developing, articulating, and disseminating under this third goal. However, InTeGrate has been a particularly powerful part of this process by foregrounding teaching about the Earth in a societal context in all of its geo-literacy materials and programming.

In addition to this shift in perception of *why* it would be desirable to increase diversity, there also seems to have been a shift in the community's understanding of *how* an increase in diversity of students who are learning about the Earth can best be accomplished. In the earlier years of trying to diversify geosciences, there was a strong focus on recruitment,¹¹³ using the same enticements that had attracted the successful geoscientists of that era to the field, notably field trips and research opportunities.

Gradually, an understanding has been constructed that enticing recruitment programs are not sufficient, that more is needed. Drawing from the experience and viewpoints of faculty attendees to SERC workshops (InTeGrate as well as other programs) and literature on broadening participation in other STEM fields,¹¹⁴ a more nuanced theory of change has emerged. With a shorthand label of Attract-Support-Prepare, this way of thinking about diversity and inclusion considers a longer arc of the student trajectory and more aspects of the student's experience (McDaris, et al., 2019).¹¹⁵ "Attract" is less about marketing, and more about understanding students' and families' perceptions about geosciences, revealing how geoscience is relevant to students' concerns, and offering opportunities to experience the practices of science. "Support" includes providing academic support, but also includes financial support, mentoring and advising, and a sense of belonging. "Prepare" refers to preparing students for a successful transition into the workforce, through internships, real-world experiences, and practice in workforce skills such as working in teams, problem solving, and working with data. InTeGrate has contributed to the development of this model for how to increase diversity of geoscience graduates, and has also tried hard to spread this emerging model throughout its sphere of influence, through webinars, workshops, websites, and Implementation Programs.¹¹⁶

& J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 3-24.

¹¹³ e.g. Huntoon, J. E., Peach, C. A., & Hopkins, J. (2005). Geoscience Education and Diversity: Vision for the Future and Strategies for Success. Report of the Second Geoscience Education Working Group: National Science Foundation Directorate for Geosciences.

¹¹⁴ Literature on broadening participation that has been especially influential in the Geo Education community includes: Tsui, L. (2007). Effective strategies to increase diversity in STEM fields: A review of the research literature. *The Journal of Negro Education*, 76(4), pp. 555-581 (central to the HBCU GeoPaths proposal). Chávez, A. F., & Longerbeam, S. D. (2016) Teaching Across Cultural Strengths: A Guide to Balancing Integrated and Individual Cultural Frameworks in College Teaching: Stylus Publishing (underpinned the University of Northern Colorado IP model for supporting diverse students.) Jolly, E. J., Campbell, P. B., & Perlman, L. (2004). Engagement, Capacity and Continuity: A trilogy for student success. A report commissioned by the GE Foundation, at: <http://www.campbell-kibler.com/trilogy.pdf>. (influential to planning IP program). Gross, D. S., Iverson, E., Willett, G., & Manduca, C. (2015). Broadening access to science with support for the whole student in a residential liberal arts college. *Journal of College Science Teaching*, 44(8), pp. 99-107.

¹¹⁵ McDaris, J. R., Iverson, E. R. Manduca C. A., and Huyck Orr, C. (2019). Teach the Earth: Making the connection between research and practice in broadening participation, *Journal of Geoscience Education*, DOI: 10.1080/10899995.2019.1616272

¹¹⁶ Recruiting, Retention & Diversity Theme at Rendezvous: https://serc.carleton.edu/earth_rendezvous/2018/program/theme_recruitretain.html. Example webinar: Supporting all students through active learning: https://serc.carleton.edu/integrate/workshops/webinars/2018_2019/active_support_students/index.html. Example workshop: Pan-African approaches to teaching Geosciences: <https://serc.carleton.edu/integrate/workshops/african-education/index.html>. For InTeGrate's diversity web resources, begin here: <https://serc.carleton.edu/integrate/programs/diversity/index.html>

At present, it is not possible to quantify the extent to which there may have been a shift over time among geoscience educators in either their goals for diversifying geoscience education or their understanding of strategies that might contribute to broadening participation--let alone the extent to which InTeGrate may have been a contributing factor. This important, but hard to pin down, potential impact could be addressed if the NAGT faculty survey is repeated in 2019 or 2020. The survey includes items that probe the extent to which respondents used practices that support diversity, equity and inclusion in the geosciences,¹¹⁷ and survey response data can be combined with ITG-involvement categories to investigate possible InTeGrate influence.

Sub-claim 2D: InTeGrate has created models for providing Earth learning opportunities for students at institutions with no geo department or limited geo faculty.

Distance learning model: Penn State

The Pennsylvania State University (PSU) IP developed a model for using web-based technology to deliver interdisciplinary sustainability education to large numbers of students, while retaining InTeGrate's focus on active-learning pedagogy and use of authentic data.¹¹⁸ Five full semesters of new content were developed.¹¹⁹ All were piloted in a blended format (content delivered by video and reading out of class, plus one face-to-face session per week for interactive work), and three are now taught in fully online format. The IP spanned Penn State's flagship campus at University Park, plus five other PSU campuses throughout the state, most of which have limited geoscience faculty. A series of webinars brought together the faculty from the multiple campuses for planning and professional development. The goal for many of the campuses was to have general education and/or Intro instruction provided by system-wide online courses so as to free up the limited geoscience faculty to teach upper level courses and thus make a full major. Within the Penn State System, the InTeGrate courses contributed to a new 12-credit online undergraduate Certificate and an 18-credit minor in Earth Sustainability, which are now offered to students around the world via Penn State's World Campus.¹²⁰ As of August 2019, there were 170 students enrolled in the certificate program, representing 15 countries; however, the more demanding minor had only 3 students enrolled.¹²¹

The PSU IP team also led an InTeGrate workshop on Teaching about Earth Online and a dedicated session at the Geological Society of America 2017 National Conference.¹²² Many of the lessons about online education learned from the Penn State IP effort, and presented at the workshop and the GSA session, replicate those known from other disciplines. However, there were also innovative approaches to

¹¹⁷ Beane, R. J., Macdonald, R. H., & McNeal, K. S. (2018). National Geoscience Faculty Survey results on education practices that support diversity and inclusion in undergraduate courses. *Geological Society of America Abstracts with Program* (Paper 159-4). <https://gsa.confex.com/gsa/2018AM/meetingapp.cgi/Paper/318189>

¹¹⁸ InTeGrate Program Models >The Pennsylvania State University: Distance Learning Courses: <https://serc.carleton.edu/integrate/programs/implementation/program5/index.html>

¹¹⁹ InTeGrate Program Models> Penn State IP> Improving Teaching & Learning> Courses & Materials: <https://serc.carleton.edu/integrate/programs/implementation/program5/materials.html>

¹²⁰ Penn State World Campus Undergraduate Certificate in Earth Sustainability: Program Overview: <https://www.worldcampus.psu.edu/degrees-and-certificates/penn-state-online-earth-sustainability-certificate/overview>. Earth Sustainability Minor: <https://www.worldcampus.psu.edu/degrees-and-certificates/penn-state-online-earth-sustainability-minor/overview>.

¹²¹ Source of enrollment data: email and spreadsheet from Tim Bralower, Aug 24, 2019, and follow-up email Sept 23, 2019.

¹²² Workshops & Webinars > Teaching about Earth Online Workshop: https://serc.carleton.edu/integrate/workshops/online_learning/index.html (May 30 – June 1, 2017). Geological Society of America National Conference (Seattle, 22 October 2017), Session No. 46: Teaching about the Earth Online: <https://gsa.confex.com/gsa/2017AM/meetingapp.cgi/Session/43077>.

geoscience-specific challenges, such as digital rock samples for online labs and virtual field trip experiences.¹²³

In addition to the coordinated cluster of Penn State courses, several individual InTeGrate modules were piloted in an online or hybrid instructional mode in parallel with the face-to-face enactments. The challenges and affordances of the online adaptation are documented in instructors' stories and publications. Boger et al. (2019) conducted their pilot testing online in a school of Natural Resources, face-to-face in an interdisciplinary program in urban sustainability, and face-to-face in a History course.¹²⁴ The required collaborative group work was conducted via Skype, and the gallery walk among final projects became an assignment to review and comment on the presentations posted in the class space by other groups. Although the online delivery required modifying some activities, the fact that all student-facing instructional materials were already web-published was helpful to the online adapters.

Send or lend instructors model: Stanford

Stanford University's IP¹²⁵ developed a model in which graduate students and postdocs from an institution with strong geoscience expertise were deployed to local institutions of higher education in which geoscience teaching expertise was relatively weak, bringing with them both geo expertise and InTeGrate teaching materials. All of partnering schools were either 2YC's, MSI's or both. The Stanford students/postdocs were paired with an experienced faculty member from the host school, and valued the opportunity to gain teaching experience. Following a professional development workshop on InTeGrate and active learning, program students taught as guests in their mentor's classroom, using InTeGrate materials. Both the mentor teachers and the Stanford students/postdocs expressed satisfaction with their experience in interviews and surveys. However, the model was not sustainable. Expenses included hiring a person responsible for day-to-day management of project activities, PD workshop costs, and stipends for the Stanford students/postdocs. After 2 years of ITG funding, Stanford continued the funding for one more year. The model did not stress building capacity among the faculty of the 2YC's and MSI's or building community among faculty at the various institutions, so when then the Stanford participants stopped coming, there would have been little to no enduring impact at the receiving institutions.

Sub-claim 2E: Individual faculty nationwide are finding, accessing, and using quality Earth-related curriculum resources, pedagogical strategies, and program-strengthening strategies, via InTeGrate's websites, publications, and webinars.

Data sources and reliability for curriculum materials uptake

The project has made a concerted effort to document how many instructors have used InTeGrate instructional materials, how many course enactments those instructors taught, and how many students have been taught in those courses. Sources of data include:

¹²³ Anbar, A.D. and C. Bentley (2017). Proposing a digital teaching network for virtual field experiences: <https://gsa.confex.com/gsa/2017AM/meetingapp.cgi/Paper/308015>. Bentley, C. (2017). Digital samples for online labs and virtual field experience: <https://gsa.confex.com/gsa/2017AM/webprogram/Paper298724.html>.

¹²⁴ Boger, R., Low, R. D., & Potter, A. E. (2019). Tackling the wicked problem of global food security: Engaging undergraduates through ArcGIS online. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary teaching about Earth and the environment for a sustainable future*. Switzerland: Springer, pp. 159-177.

¹²⁵ Stanford University: MSI and 2YC Teaching Program: <https://serc.carleton.edu/integrate/programs/implementation/program6/index.html>
Also Bellamy, A. S., Carrillo, G., & Nelson, T. W. (2019). Creating opportunities to teach and engage with undergraduates and faculty at two-year colleges and Minority Serving Institutions. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp.329-360.

- *Course Overview Pages:* When materials developers or non-developer pilot teachers signed up to conduct a pilot test of an InTeGrate module or course, they filled out an online form which asked about the nature of the course and the number of students enrolled. Similar or identical forms were filled out by some of the IP faculty, the members of the HBCU Working Group, and members of the research team.
- *Instructor Access Request Forms:* These forms are used to verify that a person is an instructor, and should therefore be able to access the “teacher stash” associated with InTeGrate materials. The teacher stash includes information such as scoring keys for student assessments. The form asks for institution, course title, student count, and when the course was or will be taught.
- *InTeGrate Materials Interest Forms:* At the bottom of the front page of the website for each InTeGrate-developed course or module, there is a link to “Join the Community.” This offers a link to “Tell us about your use of InTeGrate teaching materials,” which asks, among other things, for the instructors’ contact information, course title, and approximately how many students were in the course.¹²⁶ In addition, selected other pages within the InTeGrate website have a link to a generic version of the same survey but do not sign the respondent up for a community.¹²⁷
- *“Reach survey”:* InTeGrate designed short on-line surveys¹²⁸ that invited reflections on various aspects of the respondent’s InTeGrate involvement. The first reach survey was conducted in 2016, asking materials developers about the use they had made of InTeGrate materials subsequent to their pilot test. Also in 2016, a reach survey was sent to all workshop and webinar participants. In Fall 2017 and Spring 2018, invitations to participate were distributed widely, both to the email list of all participants in all InTeGrate programs as well as to the broader geoscience education community. Although the questions differed from survey to survey, all asked respondents to estimate how many students they had taught during a specified time frame.

Under-counting: Numbers of enactments and students from the Course Overview Pages are thought to be close to accurate, as project staff were in regular communications with these instructors. The Site Interest Forms and Reach Surveys were intended to capture data about enactments of InTeGrate teaching materials by instructors who were not formally enrolled in an organized, mentored, sustained InTeGrate professional development program. Although an effort was made to reach as widely as possible, it is inevitable that there were instructors who didn’t get the message, didn’t see the link, or weren’t motivated to respond, so these numbers are almost certainly an underestimate, perhaps a large underestimate.

Double-counting: All four of the data sources above were confidential, but not anonymous. An effort was made by the SERC staff to avoiding counting individual enactments more than once.

Considering the possible sources of over-counting and under-counting, it seems that the numbers presented below, of faculty, students and courses using InTeGrate materials, should be viewed as a lower bound. The actual numbers are unknowable, but probably higher.

¹²⁶ An example is at: https://serc.carleton.edu/integrate/teaching_materials/change_inthe_air/community.html. Note that for instructors who have already registered their course(s) with InTeGrate in another context, the form offers a chance to link to any existing prior record. This is intended to prevent double counting of instructors, courses, and students.

¹²⁷ https://serc.carleton.edu/integrate/teaching_materials/community_use/use_reporting.html

¹²⁸ The Spring 2018 version of the Reach Survey can be viewed here: https://serc.carleton.edu/integrate/participate/2018_reach. Earlier versions are linked from https://serc.carleton.edu/integrate/about/faculty_surveys.html

Uptake of curriculum materials

Exhibit III-17 (upper) shows the cumulative number of courses taught with ITG-influenced materials or ideas, for which InTeGrate has positive documentation according to one of the methods enumerated in the previous section. Cumulative number of courses was low during the years of developing and piloting materials, and then rose rapidly as more instructional materials were published (see publication date data in Claim 1 Exhibit II-17). As of Fall 2018, the tally had exceeded 3,000 enactments.¹²⁹

Exhibit III-17 (lower) shows the cumulative number of students taught during those documented enactments. Through the 2017-2018 academic year, InTeGrate is documented to have impacted more than 110,000 students. The student numbers are subdivided by the way in which each student's instructor had engaged with InTeGrate.¹³⁰ "Highly engaged" instructors are members of the Assessment Team, Research Team, IP Leadership, or Material Developers. "Implementation Program Team" are IP members (not leaders).¹³¹ "Workshop/webinar" faculty attended at least one InTeGrate workshop or webinar. "Web only" faculty reported use of InTeGrate materials, but did not attend any InTeGrate PD events.

In the 2012-2013, 2013-2014, and 2014-2015 academic years, usage was low and dominated by the Materials Developers (Exhibit III-18). Reported student impact by faculty members who received stipends from the project—the materials developers (within the highly engaged category) and the IP team members—peaked midway through the project, in the 2015-2016 school year. By 2015-2016, web-only and workshop/webinar instructors accounted for approximately half of the student contacts, and in subsequent years, that fraction continued to grow. Reported student impact among the unpaid faculty who found InTeGrate materials via the web continued to accelerate as the project wound down. In the final survey year, covering 2017-2018, nearly 40,000 students were impacted by InTeGrate. Of these, 60% (23,000+) were taught by instructors whose strongest contact with InTeGrate had come via the worldwide web (Exhibit III-18 lower).

The final approach that the project used to gauge the reach of InTeGrate's influence was by tallying the number of unique faculty members for whom the project has affirmative evidence that they have taught with InTeGrate (Exhibit III-19) and monitoring how this number grew over time. This differs from the number of enactments discussed above because individuals who reported teaching multiple ITG-influenced courses (or the same course in multiple terms) are counted only once. "Teaching with InTeGrate" means that they adopted or adapted InTeGrate materials or assessments or their teaching was

¹²⁹ Data from K. Sheriff, SERC, November 2018, in Excel file classroom_2018_ks. By comparison, Martinez & Baker (2006) estimated that there were 400,000 students enrolled in an introductory geoscience course in 2004-2005. Martinez, C., & Baker, M. A. (2006). Introductory Geoscience Enrollment in the United States: Academic Year 2004-2005. (pp. 10): American Geological Institute, Geoscience Workforce Program, online at: <https://www.americangeosciences.org/sites/default/files/gw-06-001.pdf>.

¹³⁰ These instructor engagement categories are closely related to the ITG engagement categories used in presenting the NAGT faculty survey data (Claim 1C section "Instructional practices as a function of amount of InTeGrate involvement," and Claim 3D section "NAGT national survey of geoscience faculty."). Although the definitions are closely related, the samples are not the same, because some individuals did the NAGT survey without ever teaching with ITG materials—and vice versa. "Highly engaged" here is defined identically to SuperParticipant in NAGT results. People shown as Workshop/webinar here would be a "Synchronous Participant" in NAGT. IP team members who did the NAGT survey were included in "Synchronous Participant." "Web only" here is similar to "Asynchronous Participant" in NAGT. However, it is possible to have an ITG record without having used ITG materials, for example by attending an ITG webinar. The "No ITG record" respondents of the NAGT survey data are not on this graph at all.

¹³¹ IP team members who attended an InTeGrate-wide PD event are counted in "Workshop/webinar." Note that this is not consistent with the categories used in the end of project faculty interviews (Wetzstein, Lovacich & Bragg, 2017), in which IP team members were categorized as "Mentored faculty" and distinguished from "Unmentored faculty" who had only attended workshop(s) and/or webinar(s).

inspired by InTeGrate materials or assessments. “Affirmative evidence” means that the individual indicated on a form or survey their concrete plans to teach with InTeGrate in a specific course and term.¹³² Individuals who merely indicated “I have a course or courses for which this material might be relevant” or “I’m just exploring for now” were excluded. By Spring 2019, the number of unique individual faculty members who were documented to have taught with InTeGrate over the course of the project exceeded 1500.¹³³

Web site visitors as independent evidence of continuing upward trend

Web analytics provide an independent line of evidence supporting the claim that usage of InTeGrate has grown over the duration of the project, and has continued to grow even as the publication and workshop programs have been winding down. Both the number of page views per month and the number of unique visitors per month reached a new high during the Fall semester of 2018 (Exhibit III-20). While it is not possible to know what these visitors have done with, or learned from, viewing these materials, the ebbs and flows of usage (highs during Fall and Spring semesters, lows during Summer and Winter breaks) suggest that a large fraction of these visitors are in formal education settings.

Is the number of students reached appropriate or sufficient?

The 40,000 students per year documented to have been reached by InTeGrate in 2017-2018 is a substantial number relative to the total number of students per year thought to be studying geoscience in geoscience departments. For the 2004-2005 academic year, Martinez and Baker (2006) estimated that slightly more than 400,000 students in U.S. colleges and universities were enrolled in Intro-level Geoscience courses, based on a survey sent to all active Geoscience departments and statistics on textbook sales.¹³⁴ The InTeGrate proposal stated that the “The Center seeks to impact 400,000 students during its lifetime and collect enrollment and assessment data from courses enrolling 75,000 students.”¹³⁵ InTeGrate’s 110,000+ total documented students (Exhibit III-17) exceeds the number of students for whom enrollment data was sought, but is less than the target number of “impacted” students.

The cumulative time series of courses and students taught with InTeGrate-influenced materials (Exhibit III-17) resembles the theoretical diffusion of innovation curve,¹³⁶ in which an innovation spreads from its small number of creators, to a somewhat larger group of “early adopters.” A successful

¹³² Sources of affirmative evidence that a faculty member is, has, or is planning to teach with InTeGrate include: InTeGrate Instructor Access Request form, InTeGrate Materials Interest Form, InTeGrate Materials Use Survey 2015, InTeGrate Materials Use Reporting Form (pre-2018), InTeGrate Materials Use Report (2018), Reach 2016 for Workshop and Webinar Participants, Reach 2016 for Module Authors, 2016 InTeGrate form for Module Authors, Reach 2017 (“mini-Reach”), Reach 2018, Course Setup forms (filled out by Materials Developers, Research Team, and IP faculty), Implementation Program Team Reporting. Source: Sheet “Information” of Excel file classroomuse_2018_ks11.2.18.xlsx, linked from https://serc.carleton.edu/integrate/workspace/notes_final_eval.html [Restricted access]

¹³³ Data source: Ellen Iverson & Kathryn Sheriff, August 2019, source spreadsheets and documentation are linked from page https://serc.carleton.edu/integrate/workspace/notes_final_eval.html [Restricted access] under heading “Unique Instructors per Year.”

¹³⁴ Martinez, C., & Baker, M. A. (2006). Introductory Geoscience Enrollment in the United States: Academic Year 2004-2005. (pp. 10): American Geological Institute, Geoscience Workforce Program report GW-06-001. Online at: <https://www.americangeosciences.org/sites/default/files/gw-06-001.pdf>. Anne Egger, personal communication, Feb. 2019, estimates that the total number of students enrolled in Introductory geoscience courses may have fallen since 2005, unpublished estimate made during preparation of Egger, A. E. (2018). The role of introductory Geoscience courses in preparing teachers-- and all other students--for the future: Are we making the grade? *GSA Today*, 29. doi: <https://doi.org/10.1130/GSATG393A.1>.

¹³⁵ NSF proposal for InTeGrate, page 11.

¹³⁶ Rogers, E. M. (1st edition 1962, now up to 5th edition (2003)). *Diffusion of Innovation*. New York: The Free Press of Glencoe.

innovation may then spread further to large groups of early majority and late majority, and eventually reach a small group of laggards. In InTeGrate's case, the innovation would be teaching about the Earth in the context of societal issues using active pedagogy, as embodied in InTeGrate-developed or InTeGrate-influenced curriculum materials.

Many innovations fail to make an effective transition from the Early Adopters to the Early Majority. Some authors refer to "The Chasm" between these two types of users,¹³⁷ noting that the two groups often have different priorities and motivational structures. Is InTeGrate still tapping Early Adopters, or has it begun to tap into the Early Majority? For innovations in general (not education specific), Rogers estimates that Innovators are 2.5% of the population and Early Adopters are 13.5%, and thus the "Chasm" is hit when approximately 16% of the target population have adopted the innovation. There are approximately 10,000 faculty members teaching undergraduate Geosciences in the U.S.¹³⁸ If that were InTeGrate's entire target population, Diffusion of Innovation theory would say that Early Majority would begin when approximately 1,600 faculty had adopted InTeGrate's innovations. Exhibit 111-19 suggests that InTeGrate is approaching that range of influence. In fact, InTeGrate's target faculty population is larger than just Geoscience faculty and envisioned as growing outward into non-geoscience departments, so it is difficult to know what denominator to use to calculate what percentage of potential adopters have become actual adopters/adapters. Nonetheless, it seems likely that InTeGrate is moving beyond Early Adopters and dipping its toe into the challenging waters of the Early Majority.¹³⁹

Fidelity of implementation

Some instructional materials projects place a high premium on "fidelity of implementation (FOI)," which can be defined as "the extent to which the critical components of an intended educational program, curriculum, or instructional practice are present when that program, curriculum, or practice is enacted."¹⁴⁰ For an educational research program, low FOI introduces noise in the data and may bias the outcomes if one experimental condition has higher FOI than another. In general, the further removed from the original DBER¹⁴¹ researcher or DBER-informed curriculum developer, the more the enacted curriculum tends to deviate from the as-written curriculum.

InTeGrate did not place a high premium on fidelity to the as-written curriculum. Instead, InTeGrate's materials, programming, and professional development actively encouraged faculty to adapt InTeGrate's instructional materials to best fit their own instructional context, student body, and areas of expertise and interest.¹⁴² The emphasis was on staying true to the deep principles embodied in the

¹³⁷ Moore, G.A. (2006). *Crossing the Chasm*, Harper Business, 227p. Also <https://innovateordie.com.au/2010/05/10/the-secret-to-accelerating-diffusion-of-innovation-the-16-rule-explained/> talks about differing needs and priorities and personalities of Early Adopters versus Early Majority.

¹³⁸ Manduca, C. A., Iverson, E., Luxenberg, M., Macdonald, R. H., McConnell, D. A., Mogk, D., & Tewksbury, B. (2017). Improving undergraduate STEM education: The efficacy of discipline-based professional development. *Science Advances*, 3, e1600193.

¹³⁹ For example, if InTeGrate's target audience were all 10,000 Geoscience instructors, plus 3,300 non-Geo instructors (to achieve 25% non-Geo), the 16% uptake rate (2,128 instructors) likely would have been reached in the 2017-2018 academic year according to Exhibit III-17.)

¹⁴⁰ Stains, M., & Vickrey, T. (2017). Fidelity of implementation: An overlooked yet critical construct to establish effectiveness of evidence-based instructional practices. *CBE--Life Sciences Education*, 16(1). doi: 10.1187/cbe.16-03-0113. Quote is from pages 16:rm2 to 16:rm3

¹⁴¹ DBER = Discipline Based Education Research. See Singer, S. A., Nielsen, N. R., & Schweingruber, H. A. (2012) *Discipline-based education research*. Washington, D.C.: National Academies Press.

¹⁴² For example, the web page on "Using InTeGrate Modules and Courses" has a section on "Adapting InTeGrate Materials to your Classroom": https://serc.carleton.edu/integrate/teaching_materials/adapting.html#adapt; a webinar

instructional materials rubric, while optimizing the details for one’s own context. Every InTeGrate course and module is structured as a set of separable units, and the teacher resources often include guidance on how to use individual units without the preceding or subsequent units. As of June 2018, the InTeGrate website had published 132 “Instructor Stories,”¹⁴³ almost every one of which describes some way in which the instructor deviated from the as-written curriculum.

This premise or philosophy--that better educational outcomes will be achieved if instructors are encouraged and supported in adapting the as-written curriculum materials to their context rather than nudged towards an ideal of fidelity of implementation—pervades the InTeGrate project. This stance was a premise of the InTeGrate design. It was not targeted for testing during the project, and cannot be tested retrospectively with the data in hand.

This stance reflects a deep belief in the capacity of college faculty members, working individually and in small collaborative groups, to understand their own students, to spot opportunities in their own instructional context, and to undertake curriculum development (despite the lack of curriculum development training in most college faculty’s professional preparation). Building on top of this faith in faculty, the InTeGrate project put into place a materials development infrastructure (See Claim 1 re: rubric, assessment team, publication template) that aspired to embed certain elements so deeply and so pervasively throughout the instructional materials that, no matter how thoroughly those materials were disassembled or modified, these elements would still have a good chance of carrying their weight. Based on a scan of the Instructor Stories, the elements that were most robust across the adaptation process include teaching in the context of societal problems, active learning pedagogy, and use of authentic geoscience data.¹⁴⁴

InTeGrate’s adapt-at-will stance may have been rooted in the backgrounds of the initial InTeGrate Leadership Team. They were themselves college faculty members—not DBER researchers, nor professional curriculum developers. Most were motivated by a desire to improve geoscience education and make planet Earth more sustainable, more than by advancing the frontiers of knowledge in education theory. Moreover, they were *Geoscience* faculty members. More so than most science disciplines, education about the Earth is thought to benefit from place-based education¹⁴⁵ using local examples, and thus no single as-written curriculum can be optimally effective for students in all parts of the country.¹⁴⁶

One more thought on InTeGrate’s unconcerned stance on fidelity of implementation: One could hypothesize that this stance on FOI contributed to InTeGrate’s order of magnitude spread from the

on “Adapting InTeGrate Materials to Best Effect” was offered by a Leadership Team Member in October 2015, with documentation at: https://serc.carleton.edu/integrate/workshops/webinars/2015_2016/adapt.html#res

¹⁴³ All instructor stories are linked from:

https://serc.carleton.edu/integrate/teaching_materials/community_use/instructor_stor.html. Instructor stories for individual modules and courses are prominently linked from the home page for that module or course.

¹⁴⁴ One way to reconcile InTeGrate’s approach with the FOI literature is to say that these broad elements are, in fact, the “critical components” that must be in place to consider an InTeGrate-influenced enactment to have been sufficiently faithful to the designers’ intent. However, these InTeGrate elements are much broader than those typical in the FOI literature, for example, in their framework of critical components for peer instruction, Stains & Vickrey (2017, *op. cit.*, p. 11,8) include such fine-grained details as “The instructor listens to students’ conversations during peer discussion,” and “Students think about the question individually during the first vote.”

¹⁴⁵ e.g. Semken, S., & Freeman, C. B. (2008). Sense of place in the practice and assessment of place-based science teaching. *Science Education*, 92(6), pp. 1042-1057.

¹⁴⁶ The reasoning is that an as-written curriculum using an exemplary watershed or stratigraphic section, for example, may not be as educative as an adapted curriculum using a locally-significant watershed or stratigraphic section. Even if the unused exemplar might have been a cleaner illustration of an important geoscience concept, students benefit from studying localities they have visited and can experience personally, and that are connected to their own experienced cultural context, economy, and sense of place.

hundred or so materials developers to 1500+ instructors of Exhibit III-19. InTeGrate’s “sales pitch” to prospective materials adaptors stressed how flexible the materials are, how they can be adapted to fit one’s own goals and context, and how it is possible to start by trying out just a small bit of InTeGrate instructional material and see how it goes before committing to the entire module or course. That approach was probably more attractive to potential adopters than an invitation to completely replace 2-3 entire weeks of one’s course (the stated length of a typical InTeGrate module) or adopt an entire course.

Uptake of program-strengthening strategies

InTeGrate worked to develop and disseminate program-strengthening strategies, such as “Increase the Diversity of your Graduates” and “Strengthen Workforce Preparation in your Program.” Much of this development was done in the context of the Implementation Programs and workshops that were intended to gather resources for the IPs. Many of the program-level strategies were then carried over into the Traveling Workshop Program, where they served as the basis for new elective modules (further information in Claim 3).

The program-level strategies were documented and gathered into websites¹⁴⁷ where they could be picked up and implemented by individuals and at institutions that were not enrolled in InTeGrate programs. The Leadership Team is aware of specific instances where these strategies have been picked up and implemented by web-users, publication-readers, or webinar attendees. But there is no project-wide data on the extent to which individuals or programs may be using InTeGrate’s program-strengthening strategies outside of the Traveling Workshops and Implementation Programs, nor on how many students they may have impacted.

Sustaining Change to the Education System

InTeGrate can be viewed as a system, or as an intervention that has sought to effect changes to the larger nation-wide system of Earth education (Kastens & Manduca, 2017).¹⁴⁸ When viewing InTeGrate as an intervention into the larger system, the relevant question for evaluation then becomes, “how have actions undertaken by InTeGrate changed the education system in ways that will persist beyond the duration of the InTeGrate grant?” Seeking evidence of such change, the leadership of each IP was asked reflect on how they were “Sustaining Change,” and these reflections were featured prominently on the front page of each IPs website. Several recurring strategies emerged:

- New courses and programs that are designed to align synergistically with pre-existing internal and external forces for change are more likely to be approved and implemented successfully
- Catalyze or invigorate a community of practice to create lasting change
- Co-write a proposal to continue or extend activities begun during the IP

Design, gain approval for, and implement a new course or program:

Several IPs used the InTeGrate funding and structure to advance a new or revised degree program or certificate program. The Savannah State IP established a multi-course certificate program in Coastal Hazards and Risks Management, while the Claflin IP established an 8-hour certificate in “Awareness and education for community natural disaster mitigation and preparedness,” which they are trying to make available to all freshman. The Grand Valley IP pushed through a complete revision to their university’s degree pathway in Integrated Science Secondary Education, ending up with a degree program (major) whose graduates are certified to teach any science content area in grades 6-12 in Michigan. The Penn

¹⁴⁷ Linked from <https://serc.carleton.edu/integrate/programs/index.html>

¹⁴⁸ Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230.

State IP was part of a larger effort, with funding from the university and NASA, as well as InTeGrate, to develop a 12-credit undergraduate Certificate in Earth Sustainability and an 18-credit undergraduate Minor in Earth Sustainability.¹⁴⁹

In academia, program requirements are the ground rules that lay out the allowable pathways that a student may follow in order to reach the goal of a degree or certificate. In Meadows' (1999) classic exposition of *Leverage Points to Intervene in a System*, “changing the rules of the system” sits at the cross-over point between leverage points that are increasingly powerful and leverage points that are increasingly difficult to achieve.¹⁵⁰ Achieving this high-leverage permanent change to the local education system happened when InTeGrate-funded activities aligned synergistically with pre-existing internal and external forces for change. For example, at Grand Valley, changes in the state teacher certification requirements had led to changes in the state science teaching job market, which had led to a perceived need to streamline and clarify the pathway to an Integrated Science Education program. The IP soared on this existing thermal updraft.

*Catalyze or invigorate a community of practice*¹⁵¹

See also the next chapter, on Claim 3, for a deeper dive into the role and value of communities of practice throughout the InTeGrate ecosystem.

Establishing a well-functioning community of practice was one recurring strategy to create lasting change, often by connecting individuals who had previously not known each other or had not been in regular contact. The Cal State Chico IP pulled together faculty who were teaching various courses along an existing General Education Sustainability Pathway. These faculty collaborated to create a purposefully designed and integrated student experience along the pathway by bringing more science into the non-STEM courses and deeper insight around societal concerns into STEM courses.¹⁵² One team member wrote: “Previously I had no contact with other instructors in my Pathway. I now have some understanding of the content they are teaching and the ways they try to introduce material to their students.”¹⁵³ The Chico IP team is working to catalyze similar collaborations for other pathways at their university.

The El Paso Higher Education Community (EpHEC) pulled together Geology faculty at the University of Texas El Paso, the six campuses of El Paso Community College, and the early college high schools in the El Paso area, to improve teaching about the Earth for this largely Hispanic student body. The community engaged in a very active program of faculty workshops (Aug 2015, Oct 2015, Jan 2016, Feb 2016, Sept 2016), multiple meetings addressing the revision of the articulation agreement, joint field trips (“Geoventures”), and the creation of a bridge program for transfer students. Going forward, EPCC

¹⁴⁹ Minor in Earth Sustainability: <https://www.worldcampus.psu.edu/degrees-and-certificates/penn-state-online-earth-sustainability-minor/courses>. Certificate in Earth Sustainability: <https://www.worldcampus.psu.edu/degrees-and-certificates/penn-state-online-earth-sustainability-certificate/overview>.

¹⁵⁰ Meadows, D. (1999). *Leverage Points: Places to Intervene in a Systems*: The Sustainability Institute. Online at: http://donellameadows.org/wp-content/userfiles/Leverage_Points.pdf

¹⁵¹ Support Implementation of Change>Create a Community of Practice: https://serc.carleton.edu/integrate/programs/implementation/make_change/implementation.html

¹⁵² Teasdale, R., Hatfield, C., Clements, P., Altir, L., Hankins, D., & Willard, E. (2019). Modified use of InTeGrate curriculum in the Sustainability General Education Program at California State University, Chico. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 277-296.

¹⁵³ InTeGrate Program Models > Cal State Chico > Improving Programs > Goal 2: <https://serc.carleton.edu/integrate/programs/implementation/chico/program.html#goal2>

and UTEP geology faculty plan to continue to meet together once per semester to discuss issues of common concern.¹⁵⁴

Co-write a proposal to continue or extend activities begun during the IP

At Mercer University, faculty in science, technology, mathematics and education are collaborating on a proposal for a STEM center that will include teaching gardens to increase motivation towards environmental sustainability in both University and community stakeholders.¹⁵⁵ The leader of this effort is an Environmental Science faculty member.

The Washington State teacher preparation IP laid the groundwork for a successful \$1.4M proposal to NSF's IUSE program.¹⁵⁶ The IUSE grant continues the InTeGrate IP model of collaborating across institutions of higher education involved in STEM teacher education, state agencies, and other key stakeholders, and integrates sustainability (along with engineering and computer science) into teacher preparation.

Under the leadership of Savannah State IP program leader Sue Ebanks, and with participation from other HBCU Working Group institutions, a successful proposal has been written to NSF's GeoPaths program. Called "GP-IMPACT: Expanding HBCU Pathways to Geoscience Education," the project aims to analyze and improve pre-service teacher preparation programs and curricula, with particular attention to middle school grades and use of culturally-relevant curriculum materials.¹⁵⁷

Both the Washington State and Savannah State proposals use SERC to provide "backbone" infrastructure (e.g. web-based collaboration tools) to tie their distributed network of institutions together. In addition, the Savannah-led group is using SERC for evaluation. These decisions attest that those IP leaders found the backbone functionality to be valuable during their InTeGrate experience, and the continuity in support services may have helped the post-InTeGrate projects spin up more expediently.

Less sustainable models

An approach that exhibited less ability to endure beyond the period of the InTeGrate sub-award was the strategy of sending instructors from an institution well-endowed with geoscience expertise to teach or co-teach in an institution with few or no geoscience faculty. Soon after the funding for the visiting instructors dried up, the enhanced geoscience instruction in the host institution ended. In many ways, this experience echoes the track record of NSF's GK-12 program, which also centered around having graduate student fellows with STEM expertise guest teach under the mentorship of an experienced teacher, in this case in K-12 schools. Of 188 GK-12 sites studied by Ufnar et al (2012), only 19 had sustained an in-classroom program after their NSF funding terminated, and many of those programs were greatly scaled down in number of fellows or fellows' time commitment.¹⁵⁸ Both the GK-12 program and the similarly-structured Stanford IP program were considered beneficial by their participants. But they did not achieve lasting change.

¹⁵⁴ Doser, D., & Villalobos, J. (2019). Use of InTeGrate materials to engage instructors and encourage curriculum change in the El Paso Higher Education Community. In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp.297-328.

¹⁵⁵ Mercer University IP program description:
<https://serc.carleton.edu/integrate/programs/implementation/mercer/index.html>

¹⁵⁶ Award Abstract #1625566: Collaborative Research: The Next Generation of STEM Teacher Preparation in Washington State: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1625566&HistoricalAwards=false

¹⁵⁷ Award Abstract 1802124: GP-IMPACT: Expanding HBCU Pathways for Geoscience Education:
https://www.nsf.gov/awardsearch/showAward?AWD_ID=1802124&HistoricalAwards=false

¹⁵⁸ Ufnar, J. A., Kuner, S., & Shepherd, V. L. (2012). Moving beyond GK-12. *CBE Life Sciences Education*, 11(3), pp. 293-247.

Summary of Claim 2

Claim 2 states that *InTeGrate has expanded the reach of high-quality Earth Education opportunities*. This claim addresses both outreach to targeted high-leverage audiences and uptake by individual instructors who were outside the circle of developers/testers/early adopters funded by the project.

Targeted audiences include pre-service K-12 teachers, students in non-geoscience and interdisciplinary courses, minorities underrepresented in STEM, and students at institutions with no geo department or limited geoscience faculty. For faculty who reach each of the targeted audiences, InTeGrate gathered and synthesized relevant material, held specialized workshops and webinars, and catalyzed Implementation Programs (IPs) and/or working groups. Evidence of reach to targeted audiences comes from examination of targeted web content, web analytics on targeted web content, examination of instructional materials that target interdisciplinary or non-Geo students, student and course enactments counts at IPs aiming for targeted audiences, limited GLE and IAI data broken down by student attributes, analysis of institution type and demographics of workshop attendees, and demographics of participants in key InTeGrate roles (e.g. Materials Developer).

All of the funded IPs succeeded in bringing InTeGrate ideas and/or teaching materials to their target audiences during their sub-award period. However, they vary considerably in how well they were able to effect lasting change. Based on published program models, instructor stories, surveys, presentations, and publications, at least one IP per targeted audience appears to have put down lasting roots.

Achieving uptake of pedagogical reforms and reform-based instructional materials by people outside the funded group of developers and testers has historically been a stumbling block for many NSF education projects. Such uptake is difficult to achieve and difficult to document. InTeGrate's evidence of uptake comes from "reach surveys" solicited by email, pop-up surveys presented to website users, and forms filled out by faculty who ask for access to instructor-only protected materials or who registered a course through the pilot testing or IP program. Through these methods, InTeGrate has documented impact on 110,000+ students at nearly 1,000 institutions of higher education.¹⁵⁹ Given incomplete response to any kind of survey, these numbers are surely an underestimate. The number of students per year taught by instructors whose only contact with InTeGrate has been via the web is increasing even as the project winds down. In the language of diffusion of innovation (Rogers, 2003), a case can be made that InTeGrate has reached beyond the "early adopters" and is now reaching the "early majority." Or in the modern vernacular, a case can be made that InTeGrate is "going viral."

¹⁵⁹ 927 unique institutions. From spreadsheet classroomuse_endofproject.xlsx, sheet Unique institutions, provided by Kathryn Sheriff and Ellen Iverson, June 2019. Linked from: https://serc.carleton.edu/admin/private_download.php?file_id=243176 [Restricted access]

Exhibit III-1: Each IP home page features a suite of “program elements” that are used by that IP (*Right*). Clicking on one of the program elements brings the user to a browse page (*Middle Panel*) that provides links to all of the other IPs that used that same program element. (*Lower*) The taxonomy of “program elements” that underlies this feature includes super-categories of Institutional Systems, Outreach, Professional Development, and Supporting Students.

The implementation showcases:

Alumni Program	Interdepartmental Collaboration
Diversity/Inclusion	Preparing Future Teachers
In-Service Teacher Training	Student Engagement

Program Elements

Each of the implementation programs contained a suite of components aimed at furthering the goals of the program. This browse allows you to look for all of the programs that had similar components as a way of seeing how these efforts worked in particular contexts.

Current Search Limits:

Program Components [Institutional Systems](#) > Interdepartmental Collaboration

Results 1 - 8 of 8 matches

Refine the Results ↓

Program Components [Show all](#)
[Institutional Systems](#) > [Interdepartmental Collaboration](#)
 8 matches

[Cultivating Sustainability at Shippensburg University](#)

Sean Cornell, Shippensburg University of Pennsylvania; Ben Galluzzo, Shippensburg University of Pennsylvania; Tim Hawkins, Shippensburg University of Pennsylvania; Claire Jantz, Shippensburg University of Pennsylvania; George Pomeroy, Shippensburg University of Pennsylvania; Nathan Thomas, Shippensburg University of Pennsylvania; Kay Williams, Shippensburg University of Pennsylvania

Cultivating Sustainability Through General Education Coursework, Professional Development, and High-Impact Co-Curricular Programming and Career Development at Shippensburg University Founded in 1871, Shippensburg ...

[Claflin University - CU InTeGrated!](#)

Camellia Kantor, Claflin University; Mihail Kantor, Claflin University; Anisah Bagasra, Claflin University; Deborah Laufersweiler-Dwyer, Claflin University; Randall Harris, Claflin University; Anthony Rizzuti, Claflin University; Cynthia Duncan Joseph, Claflin University; Rodney Hudson, Claflin University; Gloria McCutcheon, Claflin University

Lead by a group of nine motivated faculty and staff, the program managed to expand on CU's institutional efforts and to show our commitment to sustainability and leadership among other HBCUs from across the ...

Institutional Systems (11 IPs total)

- Degree Program Development (4)
- Interdepartmental Collaboration (8)
- Strategic Planning (1)

Outreach (10 total)

- Policy Change (1)
- Inter-Institutional Collaboration (6)
- Student Recruiting (1)
- Outreach to K12 Teachers and Students (1)
- Alumni Programs (2)
- In-Service Teacher Training (1)
- Public Outreach (2)

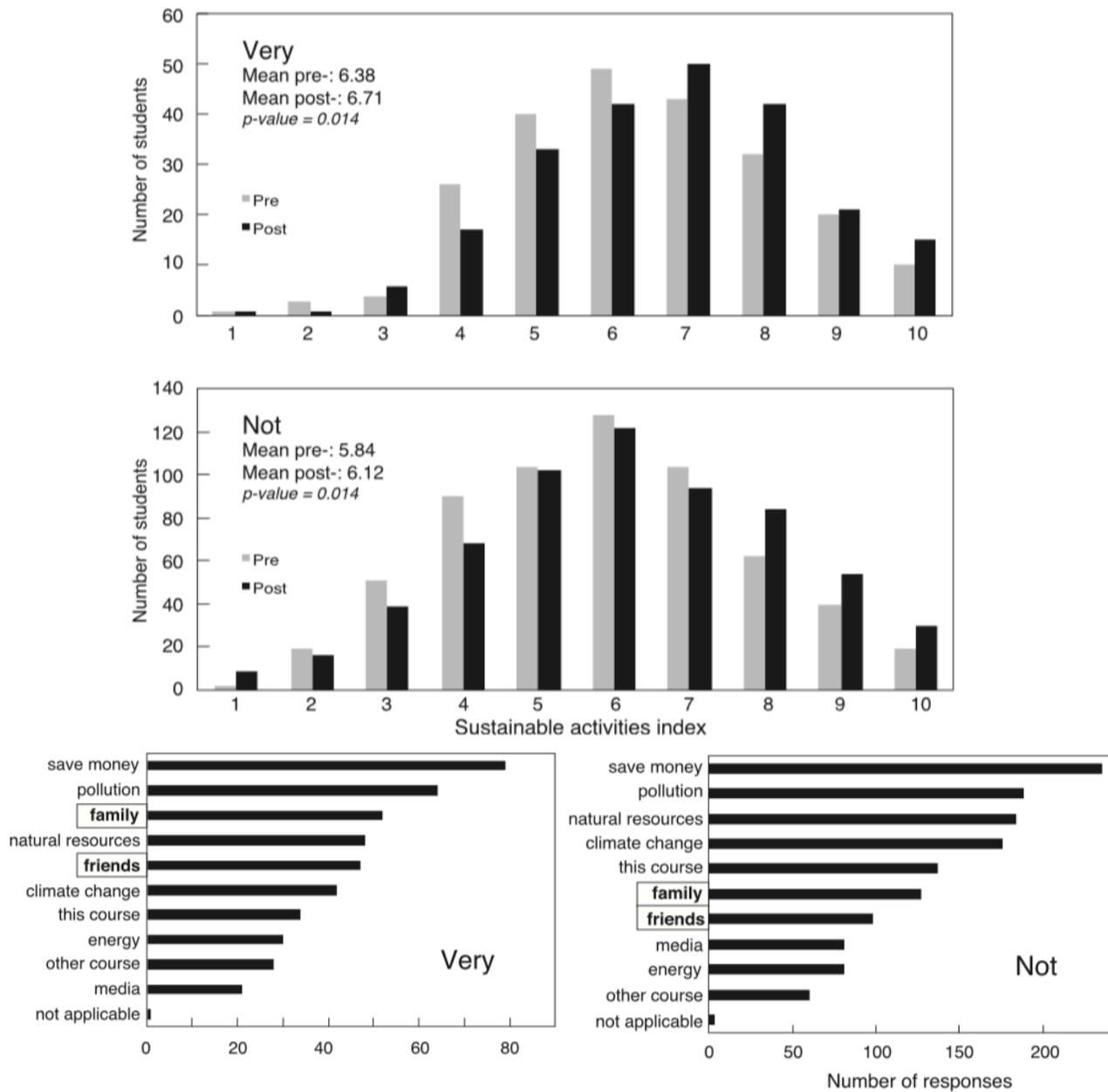
Professional Development (16 total)

- Advising and Mentoring (1)
- Curriculum Development (12)
- Diversity/inclusion (10)
- Pedagogical Training (3)
- Preparing Future Teachers (4)

Supporting Students (11 total)

- Bridge program (1)
- Cohort program (1)
- English as a Second Language (1)
- First Year Program (1)
- Internships (2)
- Professional Preparation (6)
- Student Engagement (5)
- Undergraduate Research (2)

Exhibit III-2: A subset of the information gathered by Egger et al. (2017) to inform Geoscience faculty about the prospective K-12 teachers enrolled in their classes. The illustrated data, from the InTeGrate Attitudinal Instrument, contrasts students enrolled in InTeGrate-influenced classes who are “Very Interested” in careers in K-12 education with students in those same classes who are “Not Interested” in K-12 teaching. Both before and after instruction, education-oriented students (upper panel) report engaging in more sustainability-supporting behaviors than do non-education-oriented students (middle panel.) Those interested in teaching are more likely to report that family and friends influence their decisions to engage in sustainability behaviors (lower left) than non-education-oriented students (lower right).



<i>Exhibit III-3:</i>		
InTeGrate Instructional Materials optimized for Pre-Service Teacher Education		
Format	Title & URL	Pre-service teacher features
Intro Module	Interactions between Water, Earth's Surface, and Human Activity https://serc.carleton.edu/integrate/teaching_materials/energy_and_processes/index.html	<ul style="list-style-type: none"> • Uses Earth processes observable everywhere (water). • Constructivist style (no or minimal lecture). • Aligns with NGSS DCI of “role of water...”, PE re: “develop a model to describe the cycling of water...”, and SEP of analyzing and interpreting data.
Upper division for Elementary Education majors	Soils, Systems & Society https://serc.carleton.edu/integrate/teaching_materials/soils/index.html	<ul style="list-style-type: none"> • Uses an Earth material that is locally available everywhere (Soil). • Useable even if students are under-prepared in science. • Aligns with NGSS PE “5-ESS2-1. Develop a model using an example to describe ways the geosphere, biosphere, hydrosphere, and/or atmosphere interact,” SEP “analyze and interpret data”, and DCI’s ESS2.D Weather and climate, ESS3.D Global climate change. • Culminating activity is to create a ‘Soils & Society Kit’ with lesson plans and supporting materials.
Upper division for Secondary Education majors	Exploring Geoscience Methods https://serc.carleton.edu/integrate/teaching_materials/geosci_methods/index.html	<ul style="list-style-type: none"> • Uses Earth processes observable everywhere (weather). • Aligns with NGSS PE HS-ESS3-5: “Analyze geoscience data and the results from global climate models...”; SEP “Analyzing and interpreting data”; and DCI’s ESS2.D Weather and Climate and ESS3.D Global Climate change. • Culminating activity is to build a standards-based, interdisciplinary lesson plan for a secondary science class. • Emphasizes the ‘nature of science’ insight that scientific investigations use a variety of methods
NGSS: Next Generation Science Standards. DCI: Disciplinary Core Idea in NGSS. PE: Performance Expectation in NGSS. SEP: Science & Engineering Practices in NGSS.		

Exhibit III-4: Web analytics give an indication about how large an audience has been reached by InTeGrate's various web-served materials. In general, the classroom-ready curriculum materials have attracted more visitors than the generalized information on how to improve your course or program.

Title	URL	Page Views	Visitors	Engaged Visitors
<i>Teacher Prep Focus</i>				
• Mean of 3 teacher prep modules (front page)		3,665	1,920	533
• Prepare Future Teachers	https://serc.carleton.edu/integrate/programs/teacherprep/index.html	908	516	145
• IP Section: Build Connections to Strengthen K-12 Teaching	https://serc.carleton.edu/integrate/programs/implementation/teacherprep/index.html	107	66	29
• Search and browse InTeGrate using the NGSS	https://serc.carleton.edu/integrate/teaching_materials/ngss/ngss_browse.html	450	138	80
<i>Diversity Focus</i>				
• Increasing the Diversity of your Graduates	https://serc.carleton.edu/integrate/programs/diversity/index.html	2,452	1,066	346
• Why Focus on Diversity	https://serc.carleton.edu/integrate/programs/diversity/why_diversity.html	609	384	158
• Support the Whole Student	https://serc.carleton.edu/integrate/programs/diversity/whole_student.html	1,137	463	146
• Develop Cultural Competency	https://serc.carleton.edu/integrate/programs/diversity/dev_cultural_comp.html	823	548	193
• IP section: Attract and Support Diverse Learners	https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/index.html	220	107	30
• IP section: Demonstrate Cultural Relevance	https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/cultural.html	152	97	30
<i>For comparison</i>				
• Mean of 4 highest-usage modules (front page)		8,657	3,567	1,236
• Mean of 4 medium- usage modules (front page)		1,762	836	250

Notes: *Page Views* is the number of times the page has been opened in any web browser. *Visitors* is the number of different people who have viewed the web page. *Engaged Visitors* is the subset of visitors who were on the page for at least 30 seconds and/or downloaded a file from the page. Data were collected on Nov 9-12, 2018, and include all visits since the page became public. More information about SERC's web analytics, including various caveats, is at: <https://serc.carleton.edu/serc/cms/analytics.html>. Highest and medium-usage modules were identified from classroom use database; see Exhibit II-9.

Exhibit III-5: Numbers of faculty, students, and courses reached by IPs which had improving K-12 teachers' ability to teach about the Earth as one of their major goals.

Lead institution	Goals/Focii	# Faculty	# Students	# Courses	# Institutions
Grand Valley State University	<ul style="list-style-type: none"> • Broadening Participation • Inst. without Geo program • K-12 teacher prep • Reach non-Geo majors 	10	480	4	3
Mercer University	<ul style="list-style-type: none"> • Broadening Participation • Inst. without Geo program • K-12 teacher prep • Reach non-Geo majors 	9	808	50	1
Washington State Consortium	<ul style="list-style-type: none"> • K-12 teach prep 	93	0	0	39+

Source: Orr & McDaris (2019), Table 1.

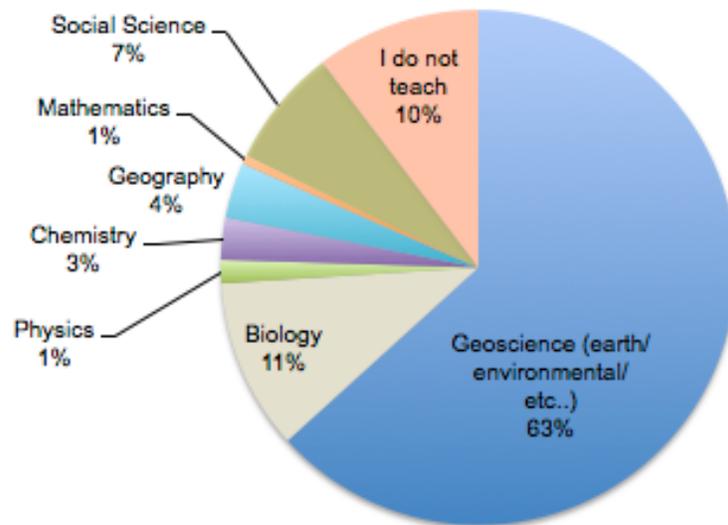
Exhibit III-6: InTeGrate instructional materials that reach beyond Geosciences

Format	Title	Intended Audience
Module	Environmental Justice & Freshwater Resources- Spanish Adaptation	Spanish courses
Module	Cli-Fi: Climate Science in Literary Texts	Humanities courses
Module	Mapping the Environment with Sensory Perceptions	Humanities courses
Module	Map your Hazards! --- Assessing Hazards, Vulnerability & Risk	Social Science courses
Module	Water Sustainability in Cities	Engineering courses
Course	Critical Zone Science	Interdisciplinary
Course	Gateway to Renewable Energy and Environmental Sustainability (GREENS)	Interdisciplinary
Module	An Ecosystem Services Approach to Water Resources	Interdisciplinary
Module	Food as the Foundation for Healthy Communities	Interdisciplinary
Module	Lead in the Environment	Interdisciplinary
Module	Water, Agriculture, and Sustainability	Interdisciplinary
Module	Major Storms and Community Resilience	Interdisciplinary
Module	Regulating Carbon Emissions to Mitigate Climate Change	Interdisciplinary
Distance-learning course	Coastal Processes, Hazards and Society	Interdisciplinary
Distance-learning course	Future of Food	Interdisciplinary
Distance-learning course	Water Science and Society	Interdisciplinary

Categorization of materials as “Materials that Extend Teaching about the Earth beyond Geoscience Programs” is based on web page at: https://serc.carleton.edu/integrate/teaching_materials/itg_materials_dev.html. Some other modules categorized by that page as “for General Education Courses” could also be adapted for interdisciplinary teaching.

Exhibit III-7: (Upper) Responses to the question “What do you teach?” on the popup survey. (Lower) Current department as recorded on the registration forms of participants in InTeGrate programs and events. Both datasets show a quarter or more of respondents coming from outside the traditional Earth-teaching venues of Earth and environmental sciences departments.

Responses to pop-up surveys (n=1778)



InTeGrate Participants by Department Discipline (n=1454)

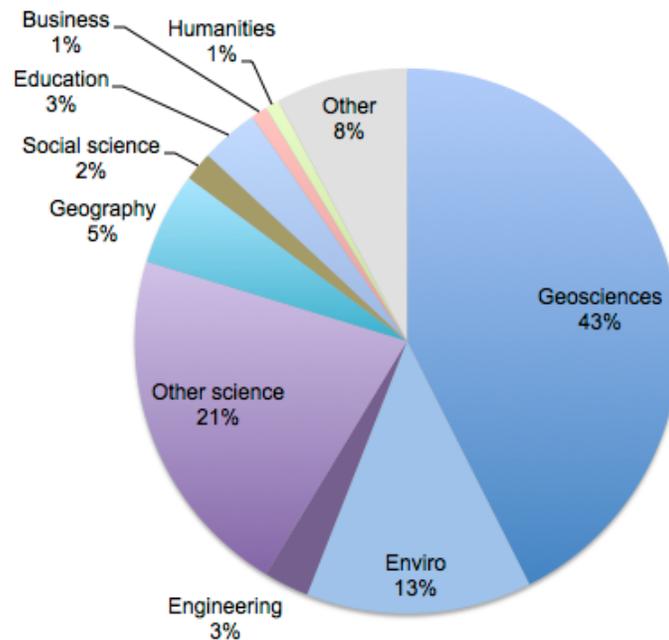


Exhibit III-8: Numbers of faculty, students, and courses reached by IPs which had teaching about the Earth in an interdisciplinary context and/or across the Liberal Arts as one of their major goals.

Lead institution	Goals/Focii	# Faculty	# Students	# Courses	# Institutions
California State University – Chico *	<ul style="list-style-type: none"> • Interdisciplinary • Broadening Particip. • Inst. without Geo prog. • Reach non-Geo majors 	9	3572	67	1
Gustavus Adolfus College	<ul style="list-style-type: none"> • Interdisciplinary • Liberal Arts • Reach non-Geo majors 	25	501	19	1
Pennsylvania State University	<ul style="list-style-type: none"> • Interdisciplinary • Inst. without Geo prog. • Reach non-Geo majors 	25	2039	70	7
University of South Dakota	<ul style="list-style-type: none"> • Interdisciplinary • Reach non-Geo majors 	16	2131	76	1
Wittenberg University	<ul style="list-style-type: none"> • Interdisciplinary • Liberal Arts • Reach non-Geo majors 	33	1258	53	2

Source: Orr & McDaris (2019), Table 1.

* Note that CSU-Chico also appears in the Broadening Participation IP table (Exhibit III-15).

Exhibit III-9: Despite considerable effort on the part of the leadership team, InTeGrate’s efforts on supporting diverse students and broadening access to Earth education got off to a slow start. Work on this issue accelerated when Dr. Felicia Davis, founder of the HBCU Green Fund (<http://hbcugreenfund.org>), joined the InTeGrate Leadership Team. She catalyzed the HBCU working group, bringing new colleagues and new viewpoints into the InTeGrate community. Photo (from <http://www.erienewsnow.com/story/37354788/sustainability-leader-felicia-davis-named-atlanta-power-woman-and-surprised-with-billboard-honoring-her-clean-energy-work>) shows Felicia in front of a billboard announcing her designation as one of the three “Atlanta Power Women” by the ATL 100 Campaign.



Exhibit III-10: Plenary speakers at the Earth Educators’ Rendezvous in the areas of diversity, inclusion, broadening participation, and culturally appropriate pedagogy.

Year	Speaker & Institution	Title & URL
2015	John Matsui University of California at Berkeley	<i>Diversifying Science—Is it as Simple as Replicating “Programs that Work”?</i> https://serc.carleton.edu/earth_rendezvous/2015/plenary_sessions/broadening.html
2015	Daniel Wildcat Haskell Indian Nations University	<i>Systems Science</i> (about holistic and complex systems thinking of First Peoples of North America) https://serc.carleton.edu/earth_rendezvous/2015/plenary_sessions/systems.html
2016	Scott Freeman University of Washington-Seattle	<i>The Positive Effects of Evidence-based Teaching on At-Risk Students (and Everybody Else)</i> https://serc.carleton.edu/earth_rendezvous/2016/program/plenary_talks/plenary_monday.html
2016	Becky Packard Mount Holyoke College	<i>Broadening Access to STEM through the Power of Daily Interactions</i> https://serc.carleton.edu/earth_rendezvous/2016/program/plenary_talks/plenary_wednesday.html
2017	Greg Cajete University of New Mexico	<i>A Pueblo Indian Sense of Place</i> https://serc.carleton.edu/earth_rendezvous/2017/program/plenary_talks/plenary_thursday.html
2018	Beverly Wright Deep South Institute for Environmental Justice	<i>Environmental Justice and Equity in the Face of Climate Change</i> https://serc.carleton.edu/earth_rendezvous/2018/program/plenary_talks/plenary_tuesday.html
2019	Rajul Pandya American Geophysical Union: Thriving Earth Exchange program	<i>We’re All in This Together: Community Science for Learning and Action</i> https://serc.carleton.edu/earth_rendezvous/2019/program/plenary_talks/plenary_tuesday.html
2019	Panel: Richard Schulerbrandt Gragg III, Florida A&M University Mintesinot Jiru Coppin State University De’Etra Young Tennessee State University Ambrose Jearld, Jr. National Technical University	<i>Grand Challenges in Earth Learning: Perspectives from Historically Black Colleges and Universities.</i> https://serc.carleton.edu/earth_rendezvous/2019/program/plenary_talks/panel_thursday.html

Exhibit III-11: InTeGrate has compiled an extensive set of strategies and best practices that departments can use to increase the diversity of their graduates and has documented use of these practices with Earth-related examples from institutions across the country. Selected strategies are shown below (compressed and edited).

<p>Attract Diverse Students to STEM</p> <ul style="list-style-type: none"> • Use Culturally Appropriate Approaches <ul style="list-style-type: none"> ○ Demonstrate cultural relevance (e.g. use local examples or issues) ○ Recognize cultural context (e.g. ways of knowing other than Western scientific approach) ○ Utilize students’ sense of place (via context-rich, place-based, culturally-informed curriculum and pedagogy) ○ Explore the impacts of socioeconomic differences (e.g. on hurricane response, power plant location) • Use Societal Issues <ul style="list-style-type: none"> ○ Community environmental challenges ○ Environmental justice across the curriculum ○ Infuse sustainability into existing courses ○ Provide opportunities for civic engagement in societal issues ○ Urban students and urban issues • Engage with K-12 Students <ul style="list-style-type: none"> ○ Summer science and math camps or field trips ○ Dual credit program with local high school • Capitalize on Introductory Courses <ul style="list-style-type: none"> ○ Build bridges between 2YC’s and 4YC’s ○ Structure intro courses with quality opportunities for student/faculty interaction • Collaborate with other institutions <ul style="list-style-type: none"> ○ K-12 schools ○ Two-year colleges ○ Four-year and research institutions 	<p>https://serc.carleton.edu/integrate/programs/diversity/attract.html</p> <p style="text-align: center;">and</p> <p>https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/cultural.html</p> <p style="text-align: center;">and</p> <p>https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/colaborate.html</p>
<p>Support the Whole Student</p> <ul style="list-style-type: none"> • Build a sense of community among students <ul style="list-style-type: none"> ○ Provide peer-to-peer support, study groups, geology club ○ Generate alumni involvement ○ Engage students in field trips ○ Break down barriers between students and faculty by holding social events ○ Minimize harm from stereotype threat and solo status ○ Take steps to support English language learners ○ Support students with disabilities • Generate involvement among larger community <ul style="list-style-type: none"> ○ Employ service learning ○ Utilize field trips ○ Involve local industry and government • Develop student motivation to succeed <ul style="list-style-type: none"> ○ Demonstrate cultural relevance and use societal and local issues ○ Tap into a suite of evidence-based strategies for motivating 	<p>https://serc.carleton.edu/integrate/programs/diversity/whole_student.html</p> <p style="text-align: center;">and</p> <p>https://serc.carleton.edu/integrate/programs/implementation/diverse_learner/community.html</p>

<p>students</p> <ul style="list-style-type: none"> ○ Integrate professional preparation into your program (see below) ○ Provide undergraduate research opportunities ● Provide academic support <ul style="list-style-type: none"> ○ Build bridges between 2YC's and 4YC's ○ Encourage use of academic support structures on campus (tutoring centers, etc.) ○ Promote advisors and mentors who are engaged with students ○ Provide opportunities for internships, research experiences, and other out-of-classroom activities 	
<p>Prepare Students for Careers</p> <ul style="list-style-type: none"> ● Illuminate career opportunities to help students prepare early <ul style="list-style-type: none"> ○ Understand the needs of the workforce (e.g. by tapping local firms and agencies for speakers and internships) ○ Integrate professional preparation into your program (in advising, curriculum development, seminars, etc.) ○ Showcase diverse career paths (especially careers beyond academia) ● Equip students with skills and experience that will help them land a job <ul style="list-style-type: none"> ○ Strengthen communication skills ○ Give credit for internships and other pre-professional opportunities ○ Incorporate opportunities for interdisciplinary coursework ○ Connect with employers and alumni; find partners in the workforce 	<p>https://serc.carleton.edu/integrate/programs/workforceprep/index.html</p>

Exhibit III-12: (Upper) Distribution of InTeGrate Materials Developers by membership in a demographic group that is underrepresented in science, and by teaching at a minority-serving institution. These measures are given as proxies for experiences that may help developers craft materials that are interesting to and effective with students from non-traditional backgrounds.

(Lower) Teams of ITG materials developers were recruited through a proposal process; teams that began the process at the same time were considered a “cohort.” Graph shows distribution of developers who were either URM’s themselves or taught at MSI’s, by cohort. Date of cohort is when they attended their planning meeting.

Materials Developers	Currently teaches at Minority Serving Institution	Does not currently teach at MSI
Member of Under-Represented Minority group	7 (6.4%)	3 (2.7%)
Not member of URM group	4 (3.6%)	96 (87.3%)

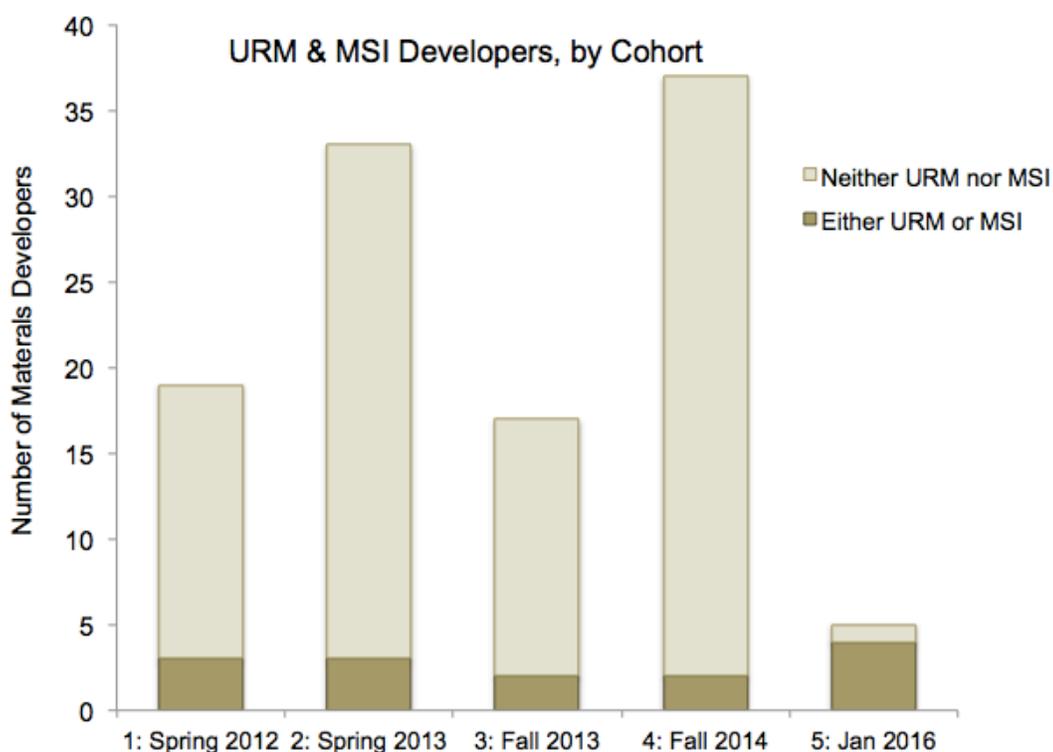


Exhibit III-13: The number and percentage of workshop attendees who reported being members of minorities under-represented in science remained small in the early years of the project, but stepped up substantially in project year 6 (academic year 2016-2017, including 2017 EER). In 2017-2018 (Yr7), the workshop program was winding down, but URM presence remained strong.

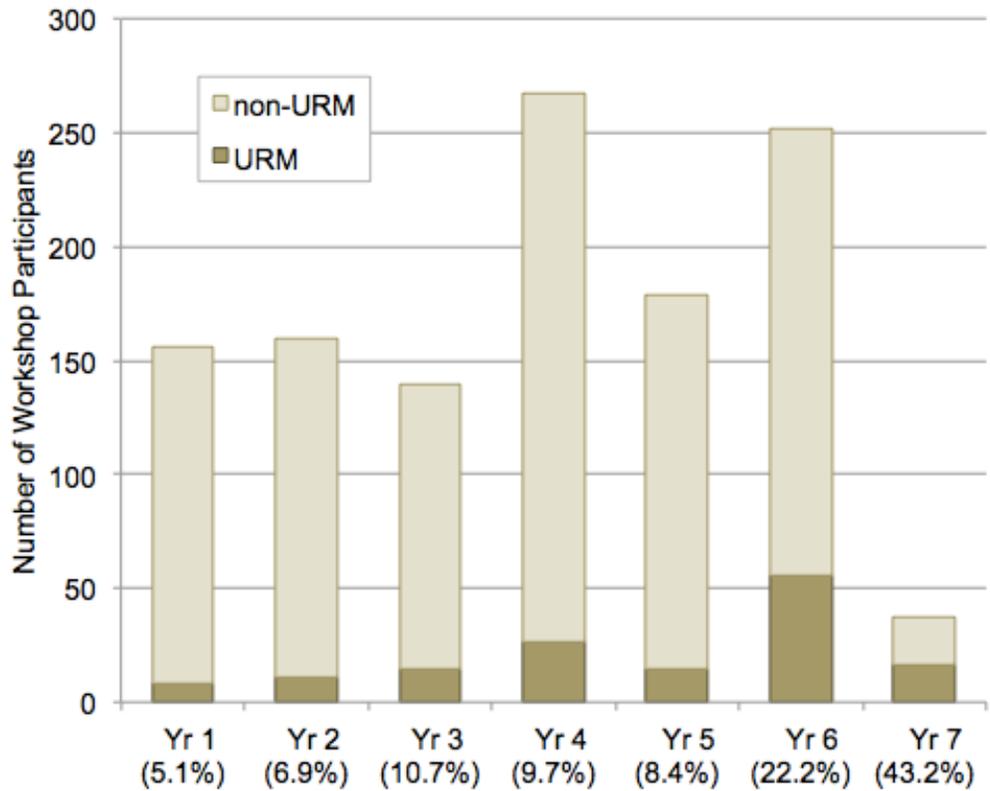


Exhibit III-14: (Upper) Data from InTeGrate’s database of classroom use of InTeGrate materials, showing reach into institution types that tend to have a high percentages of first-generation college students, students from low-income families, and students from racial and ethnic groups underrepresented in science. These numbers should be viewed as lower bounds, as not all instructors were reached by the project’s forms and surveys. *(Lower)* Each column lists the top six modules by abundance of reports by faculty that they used or are planning to use the materials to teach one course one time, summed across various reports, forms and surveys. The lists are very similar, suggesting that faculty at all institution types are finding the same materials to be of use.

Use of InTeGrate Materials at institution types with high fraction of under-represented students

	<i>Minority-serving Institutions</i>	<i>Associate’s Colleges (2YC’s)</i>
<i>Total enactments at this institution type</i>	266	426
<i>Unique Institutions</i>	38	137
<i>Unique Instructors</i>	91	196
<i>Total Student Count</i>	8,609	12,704

Most Frequently Used InTeGrate Materials, by Institution Type

<i>All Institutions</i>	<i>Minority-serving Institutions</i>	<i>Associate’s Colleges (2YC’s)</i>
1. Climate of Change 2. Humans’ Dependence on Mineral Resources 3. Carbon, Climate & Energy Resources 4. Environmental Justice & Freshwater Resources 5. Map Your Hazards! 6. Living on the Edge	1. Map Your Hazards! 2. Environmental Justice & Freshwater Resources 3. Climate of Change 4. Humans’ Dependence on Mineral Resources 5. Interactions between Water, Earth’s Surface & Human Activity 6. Living on the Edge	1. Carbon, Climate & Energy Resources 2. Humans’ Dependence on Mineral Resources 3. Climate of Change 4. Living on the Edge 5. Map Your Hazards 6. Environmental Justice & Freshwater Resources

Exhibit III-15: Numbers of faculty, students, and courses reached by IPs that had ‘Broadening Participation in Earth Learning’ as one of their major goals.

Lead institution	Goals/Focii	# Faculty	# Students	# Courses	# Institutions
California State University – Chico (HSI)	<ul style="list-style-type: none"> • Interdisciplinary • Broadening Particip. • Reach non-Geo majors 	9	3572	67	1
Clafin University (HBCU)	<ul style="list-style-type: none"> • Broadening Particip. • Inst. without Geo prog. • Reach non-Geo majors • Workforce preparation 	11	485	28	1
Grand Valley State University	<ul style="list-style-type: none"> • Broadening Particip. • (Collaborative) Inst. without Geo • K-12 teacher prep • Reach non-Geo majors 	10	480	4	1
Mercer University	<ul style="list-style-type: none"> • Broadening Particip. • K-12 teacher prep • Reach non-Geo majors 	9	808	50	1
Middle Tennessee State University	<ul style="list-style-type: none"> • Broadening Particip. • Reach non-Geo majors 	7	1204	26	1
Savannah State University (HBCU)	<ul style="list-style-type: none"> • Broadening Particip. • Inst. without Geo prog. • Reach non-Geo majors • Workforce preparation 	10	665	30	1
Stanford University	<ul style="list-style-type: none"> • Broadening Particip. • (Collaborative) Inst. without Geo prog. • Reach non-Geo majors 	26	1549	35	9
University of Illinois at Chicago (HSI)	<ul style="list-style-type: none"> • Broadening Particip. • Workforce preparation 	6	3248	30	1
University of Northern Colorado	<ul style="list-style-type: none"> • Broadening Particip. 	19	519	15	1
The University of Texas El Paso (HSI)	<ul style="list-style-type: none"> • Broadening Particip. 	44	7579	155	2

- Source: Adapted from Orr & McDaris (2019), Table 1.
- Note that Grand Valley and Mercer also appear on Exhibit III-5 and CSU—Chico also appears in Exhibit III-8.
- HBCU (Historically Black Colleges and Universities) designations from: <https://nces.ed.gov/COLLEGENAVIGATOR/?s=all&sp=4&pg=1>
- HSI (Hispanic-serving institution) designations from: <https://www2.ed.gov/about/offices/list/ope/itudes/hsi-eligibles-2016.pdf>

Exhibit III-16: The types of program encouraged under the IP call for proposals evolved and narrowed over time.

March 28, 2014 deadline	January 30, 2015 deadline	June 30, 2015 deadline
Interdisciplinary programs, majors or certificate programs with a strong geoscience component designed to prepare students for careers addressing challenges of sustainability [emphasis added].	Programs that develop <i>new interdisciplinary</i> programs, majors or certificate programs with a strong geoscience component designed to prepare students for careers addressing challenges of sustainability .	Programs that bring strong, interdisciplinary components <i>into traditional geoscience programs</i> to prepare students for careers addressing challenges of sustainability .
Programs that engage students with issues of sustainability and their scientific underpinnings and provide a continuous pathway from high school to a STEM degree .	Programs that engage students with issues of sustainability and their scientific underpinnings and provide a continuous pathway from high school to a STEM degree .	
Programs that increase the enrollment and graduation of students from groups underrepresented in the geosciences .	Programs that increase the enrollment and graduation of students from groups underrepresented in the geosciences .	Programs that increase the enrollment and graduation of students from groups underrepresented in the geosciences .
Programs that broaden access to science by introducing geoscience across the liberal arts curriculum.	Programs that broaden access to science by introducing geoscience across the liberal arts curriculum.	
Inter-institutional programs that bring geoscience into courses at institutions without geoscience faculty , including minority-serving institutions and 2YCs.	Inter-institutional programs that strengthen learning about the Earth at institutions with limited or no geoscience faculty .	Programs that strengthen learning about the Earth at institutions with limited or no geoscience faculty .
Programs that strengthen the role of geoscience in the preparation and professional development of K-12 teachers , including but not limited to, Earth science teachers.	Programs that incorporate approaches to Earth literacy for all teachers at any level, elementary or middle and high school , including but not limited to Earth science teachers.	
Programs that introduce or strengthen the role of geoscience in the preparation of STEM majors outside of the geosciences .	Programs that introduce or strengthen the role of geoscience in the preparation of STEM majors outside of the geosciences .	
Programs that facilitate the transition from college or university to the workforce .	Programs that facilitate the transition from college or university to the workforce for students with degrees that include a substantial geoscience component.	

Exhibit III-17: (Upper) Cumulative number of courses that adapted, adopted, or were influenced by ITG materials rose slowly at first and then picked up. Each count includes one enactment of one course by one instructor for one term. *(Lower)* A similarly shaped curve is seen in number of students reached. Categories of InTeGrate engagement of the instructors are explained in the text.

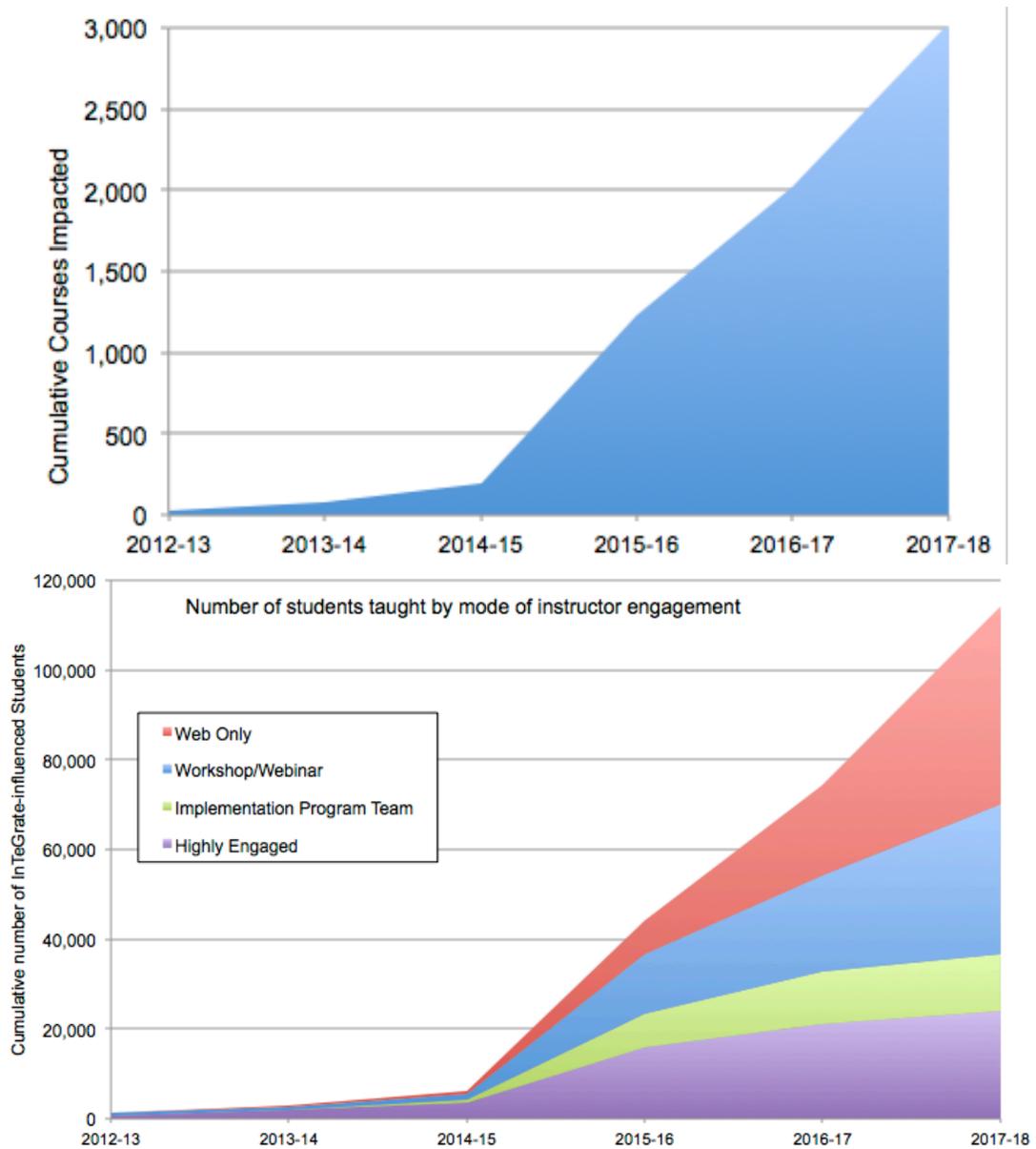


Exhibit III-18: (Upper) Number of documented students per academic year taught by instructors in each of the four InTeGrate engagement groups. (Lower) Percentage of students. The 2012-2013 academic year is omitted because some participants in that year appeared to have been misclassified with respect to engagement group. As the project matured, the role of paid participants (closed symbols) tapered, while the role of faculty members who were not part of the project team (open symbols) swelled.

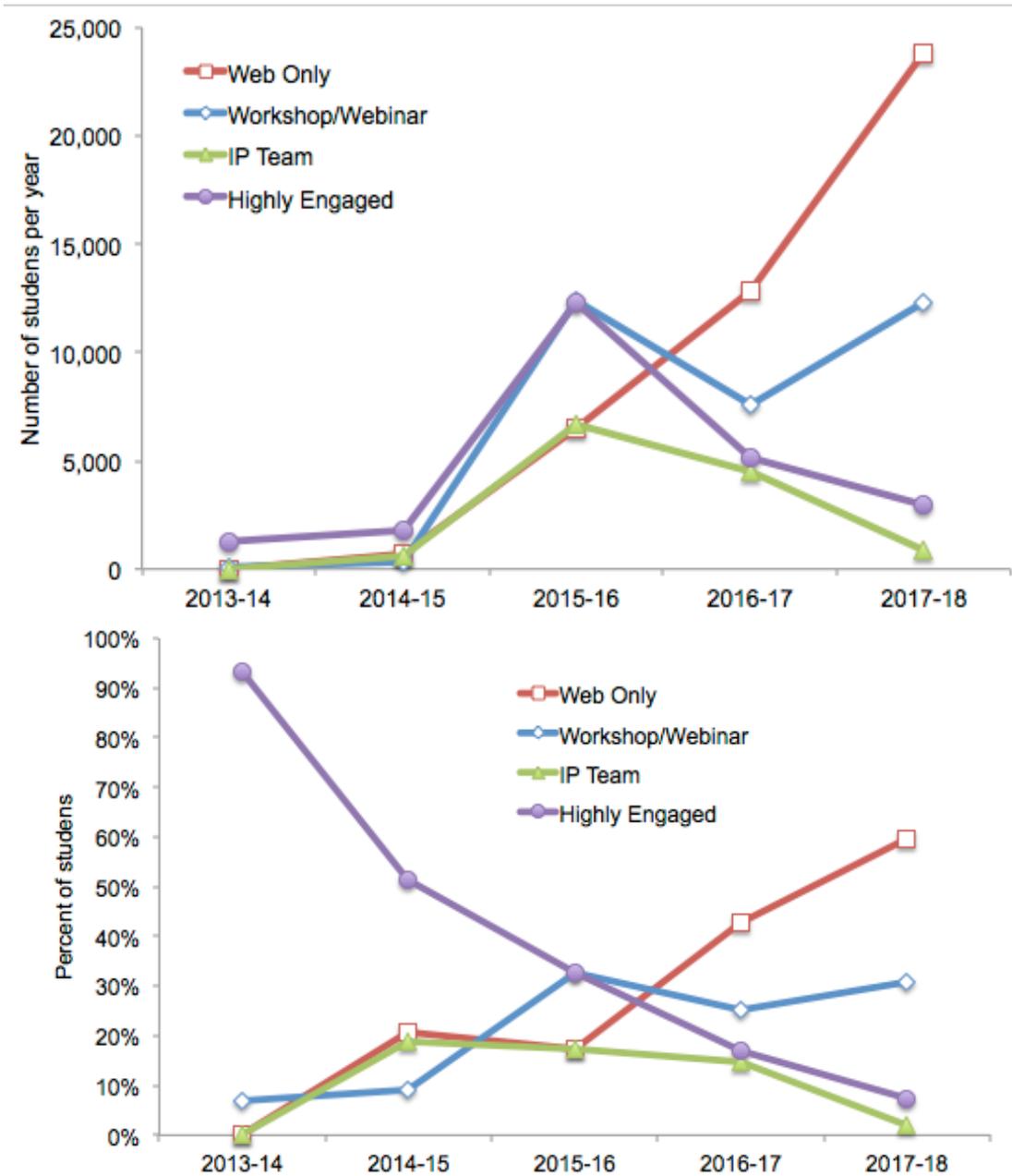


Exhibit III-19: Graph indicates the number of faculty members for which InTeGrate has affirmative evidence that they taught with InTeGrate, by academic year. The dashed line includes faculty for whom ITG has affirmative evidence that they were teaching with InTeGrate during that year. This number falls in 2018-2019 because the Reach survey was no longer being deployed. The solid line indicates the cumulative number of unique faculty members who are teaching with ITG in that year and/or taught with ITG in any previous year, i.e. the total number of individuals with documented ITG teaching experience.

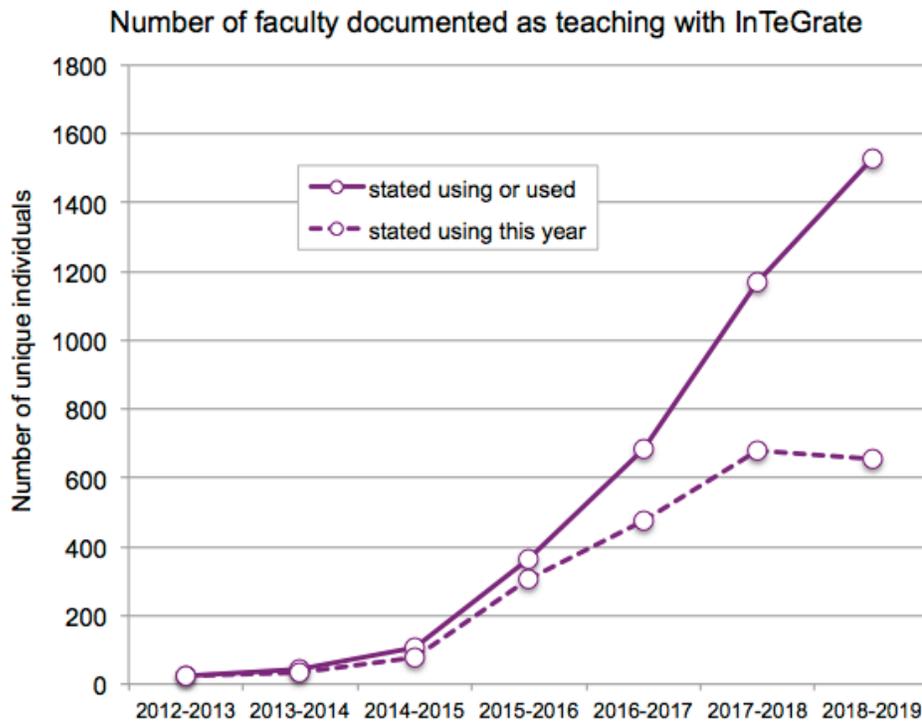
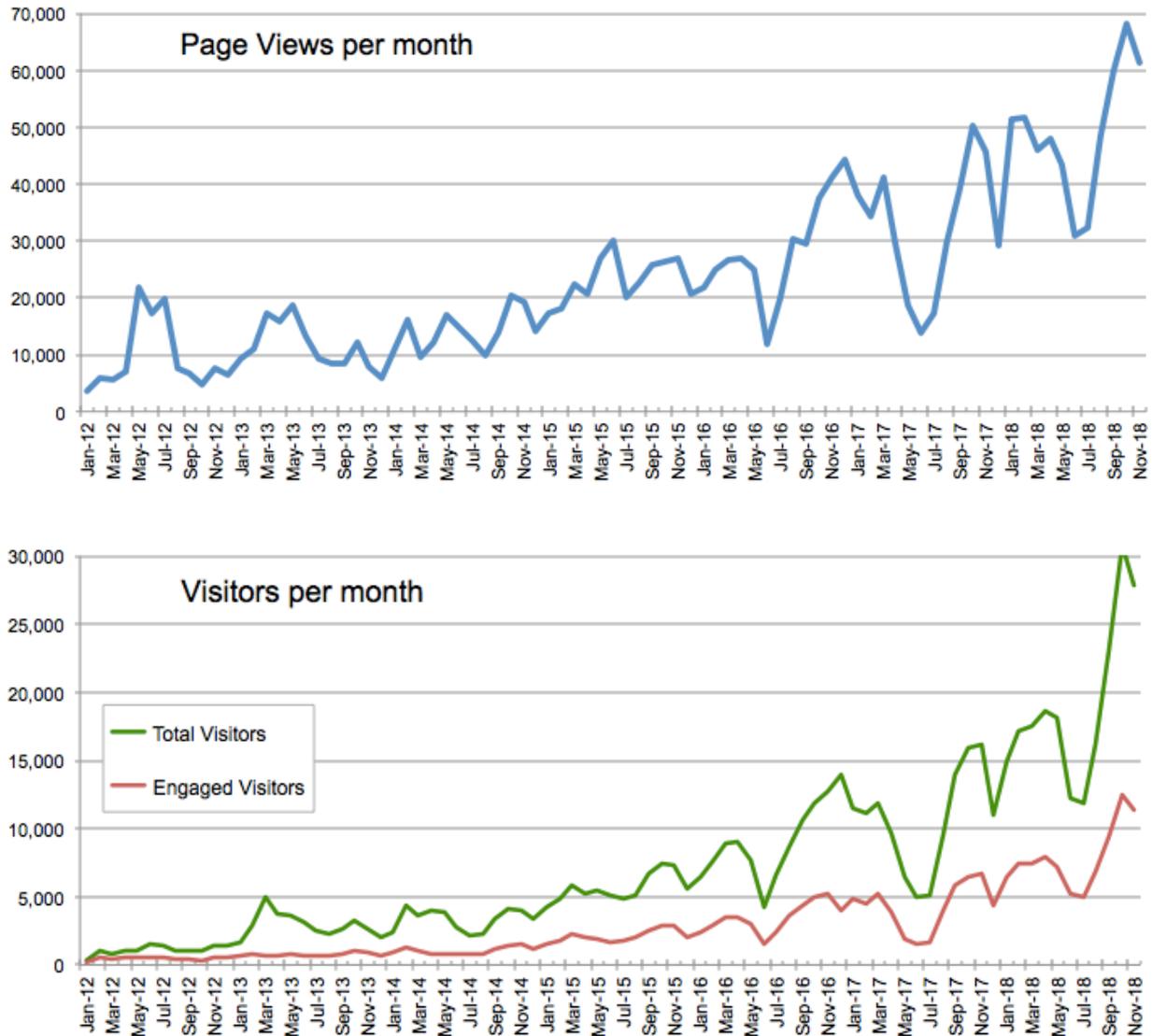


Exhibit III-20: (Lower) Monthly usage of the InTeGrate website has risen across the project and is still on an upward trajectory as the grant winds down. The academic calendar superimposes its own rhythm onto the overall upward trend, with local lows occurring during summer and winter breaks. *(Upper)* Page views per month counts the number of times any InTeGrate web page has been opened on any browser. *(Lower)* “Total Visitors” is the number of different people who have viewed one or more InTeGrate web page(s) in that month. “Engaged” visitors were on an InTeGrate page for at least 30 seconds and/or downloaded an InTeGrate file. Some caveats at: <https://serc.carleton.edu/serc/cms/analytics.html>



Chapter 4

Claim #3: InTeGrate has contributed to the growth of a robust community of practice of geoscience educators and geoscience education researchers, which has the potential to carry InTeGrate's impact into the future.

A “community of practice” (CoP) is a group of people who share a concern or a passion for something they do, and who learn how to do it better as they interact regularly. Interactions may be face-to-face, virtual, or a combination. Communities of practice have the potential to increase the effectiveness of the participating individuals by sharing insights, experiences, resources and best practices, and by inventing new practices, creating new knowledge, and developing a collective and strategic voice.¹

Although individual components of the InTeGrate portfolio may slow or terminate with the expiration of grant DUE-1125331, the project's leadership believes that the mission of InTeGrate will be carried forward by collaborative groups who have established trust, working relationships, and a shared set of goals and values through their work with InTeGrate and associated projects. Thus, establishing this community of collaborators should be seen as a central component of InTeGrate's legacy, along with the portfolio of instructional materials developed and the cohort of students educated.

This vision was expressed in the InTeGrate proposal under Program Element 3: Professional development and dissemination:

Rather than a traditional ‘top-down’ approach to professional development, this program element relies on our underpinning philosophy of an engaged community that shares and learns together. The activities within the professional development program will cultivate connections among individuals and foster their ability to learn from one another and work together to address the challenges they face individually and collectively. This model is based on the practice of the scientific community, which is highly successful in fostering innovative research, supporting diffusion of effective practices, and producing results that are of high utility.²

InTeGrate's claim to have contributed to the creation of an enduring community of practice of geoscience educators begins by showing that InTeGrate activities match the definition of CoP quoted above:

With respect to “*a group of people who share a concern or passion ... and interact regularly...*”, the shared “concern or passion” is identified as “improving education about the Earth at the undergraduate level.” Regular interactions occurred via 36 workshops, 65 online webinars, the annual Earth Educators' Rendezvous, the Traveling Workshop Program, various special purpose teams and work groups (for example, the HBCU Working Group and the Assessment Team), and within Implementation Program Teams. Although all of these groups and gatherings had multiple goals, weaving new threads into the fabric of the GeoEd Community of Practice was always an underlying purpose, and so these program elements are discussed under Claim 3. The texture of these interactions was evaluated through evaluator attendance at many convenings, interviews, surveys, and document review, especially of the extensive web work areas created by most SERC-supported workshops and meetings.

With respect to “*increase the effectiveness of the participating individuals by sharing insights, experiences, resources and best practices,*” this chapter documents that workshops, webinars, the Earth

¹ Wenger-Trayner, E., & Wenger-Trayner, B. (2015). Communities of practice: A brief introduction. <http://wenger-trayner.com/introduction-to-communities-of-practice/>

² Manduca, C.A., et al. (2011). NSF proposal: InTeGrate: Interdisciplinary Teaching of Geosciences for a Sustainable Future. p.7.

Educators' Rendezvous, and IP Teams were venues for sharing of insights, experiences, resources and best practices. This aspect of the CoP functionality was explicitly probed by lightning interviews of participants at the Earth Educators' Rendezvous and more extensive phone interviews with materials developers and IP members. This theme also emerged strongly in evaluator observation of numerous workshops and meetings, and in the "instructor stories" web-published by materials developers and IP team members.

With respect to "*inventing new practices, creating new knowledge, and developing a collective and strategic voice,*" InTeGrate's most conspicuous instances of collaborative co-construction by the community/for the community are the instructional materials and the IP program models. These codify new approaches to common problems in pedagogy and program design. In addition, the Assessment Team co-developed a suite of instruments and collaboration tools. On a smaller scale, many InTeGrate workshops include activities in which participants co-create lessons, plans, learning goals, or other mutually beneficial documents. The co-creation process and products were evaluated by interviews, surveys, evaluator participation as an ex officio member of the Assessment Team, evaluator attendance at many webinars where the outputs of materials development and IP teams were presented to the community, and examination of many co-created products.

Going beyond merely conforming to the definition of a CoP, Claim 3 also asserts that *some CoP's created or amplified during the InTeGrate era are likely to endure to carry on InTeGrate's work into the future*, because (a) participating in CoP activities feels rewarding for the participants, (b) some CoP activities have become financially and administratively independent of InTeGrate, and (c) the community now has a better grasp of what is necessary to implement an effective CoP. The feelings engendered by participating in InTeGrate's convenings have been probed by face-to-face interviews at the Rendezvous, telephone interviews of individuals with varying depths of ITG engagement, and a nationwide survey of Geoscience faculty. The three lines of evidence support an interpretation that these convenings contribute to a feeling of being a part of a mutually-beneficial community of shared interest. The financial and administrative stability of selected parts of InTeGrate's legacy have been examined through leadership interviews, evaluator participation in all Leadership Team telecons and meetings, and document review.

Finally, in carrying on InTeGrate's work, Geo-Ed CoP's will be aided by a *deeper theoretical understanding of what drives successful CoP's*. Based on observations of InTeGrate and other GeoEd groups, and partially tested by EER interviews, the InTeGrate evaluator and PI have put forward a systems dynamics model that seeks to explain how effective CoP's build success upon success through reinforcing feedback loops.

In summary, InTeGrate's claim to have contributed to the growth of a robust community of practice encompasses the following components:

Sub-claim 3A: InTeGrate has repeatedly brought together groups of people who share a concern and a passion for improving education about the Earth at the undergraduate level.

Sub-claim 3B: The groups of people brought together by InTeGrate support each other in improving their educational practice by sharing and exchanging insights, experiences, resources, and best practices.

Sub-claim 3C: Moreover, the groups of people brought together by InTeGrate sometimes invent new practices or create new knowledge.

Sub-claim 3D: These convenings contribute to a feeling of being part of a community of shared interest.

Sub-claim 3E: The national community of practice and some of the local or regional communities of practice are structured so as to be able to carry on after the end of the NSF grant.

Sub-claim 3F: InTeGrate has advanced theoretical understanding of the dynamics that make Communities of Practice effective.

* * * * *

Sub-claim 3A: InTeGrate has repeatedly brought together groups of people who share a concern and a passion for improving education about the Earth at the undergraduate level.

As proposed, and as modified

The InTeGrate proposal outlined an ambitious professional development program centered around workshops and associated websites of the sort that had proven so successful in previous GeoEd programs, especially *On the Cutting Edge* and *Building Strong Geoscience Departments*.³ In the early years of the program, the focus was to be on developing a robust understanding of current best practices, and gathering allies and ideas that could inform materials development and implementation programs. In the later years of the project, as course materials and program models became available, the focus of the workshops was intended to shift towards disseminating these products and supporting faculty in their use.

The program evolved in two ways from the proposal description. The first change was that webinars became a major vehicle for disseminating materials. Although “virtual events” had been mentioned in the proposal, by the time InTeGrate had materials and models to disseminate for adoption and adaptation in project year 3, the flexibility of virtual meeting software, and the increasing experience of GeoEd faculty with virtual conversation, made webinars a cost-effective vehicle for dissemination. The second change was that instead of multiple dissemination workshops, the face-to-face workshops in the latter part of the project were rolled into what was initially called a “mega-workshop” and later called the “Earth Educators’ Rendezvous.”

The workshops and webinars served a variety of purposes in the InTeGrate ecosystem, including dissemination of materials and ideas, training of materials developers, and recruitment of faculty to adopt or adapt materials. Whatever their other purposes, all of these convenings had as one of their purposes the intent to weave new threads into the GeoEd community of practice. For this reason, the webinar and workshop programs in their entirety are documented and discussed, here, under Claim #3: Community.

Workshops

Over its lifetime, InTeGrate sponsored or co-sponsored at least 36 workshops and 67 online webinars (Exhibits IV-1 and IV-4). InTeGrate workshops have been attended by 998 individuals, while 1,070 have attended InTeGrate webinars. Overall, 1,777 individuals have attended some kind of InTeGrate professional development event, and 599 of those have attended more than one event.⁴

Almost all InTeGrate workshops and webinars have associated websites and all webinars are recorded. The websites and recordings provide an opportunity for colleagues who couldn’t attend the real-time event

³ On the Cutting Edge (legacy site about the original project): <https://serc.carleton.edu/NAGTWorkshops/about.html>. On the Cutting Edge (active site, NAGT era): <https://serc.carleton.edu/NAGTWorkshops/index.html>. Building Strong Geoscience Departments (Legacy site about the original project): <https://serc.carleton.edu/NAGTWorkshops/departments/about/index.html>. Building Strong Departments (currently active project, extending beyond geosciences): <https://serc.carleton.edu/departments/index.html>.

⁴ Numbers of participants are from email from Kathryn Sheriff, Science Education Resource Center, February 8, 2019 and associated spreadsheet [itg_PD_data_2.8.19.xlsx](#). Numbers of workshops and webinars are from <https://serc.carleton.edu/integrate/workshops/index.html>, and are current as of June 11, 2019.

to reap some benefits nonetheless. For more on the synthesis websites that draw from multiple workshops, see “*About InTeGrate’s gather/synthesize/disseminate best practices strategy*” under Claim 2.

Exhibit IV-1 shows the history of InTeGrate workshops. As with the earlier *On the Cutting Edge* program, InTeGrate workshops were designed to be valuable to the individual participants, to the project as a whole, and to the larger GeoEd enterprise. The early workshops labeled “in-gathering workshops” in Exhibit IV-1 served the larger goal of gathering allies and ideas to inform the materials development and Implementation Programs: ideas for IP’s (for example, Workshop #1 in Exhibit IV-1), approaches for teaching geoscientific habits of mind (#3), approaches for teaching about the Earth in the context of societal problems (#4), ideas for reaching minorities underrepresented in geoscience (#6), and so on. Many of the early InTeGrate workshops were “Partnership Workshops,” cosponsored by *On the Cutting Edge* (#2, 7, 10, 12, 13, 14, and 15), or by the *Traveling Workshop Program* (#18), which offered the opportunity to bring together traditional geoscience educators with some of the more environment/sustainability-oriented educators attracted to InTeGrate’s focus on teaching in the context of societal problems.

The workshop program peaked in 2015 (project year 3), when 9 workshops were held, including the inaugural Earth Educators’ Rendezvous. That was also the year when workshops first offered access to published InTeGrate instructional materials, beginning with workshop #21. In the later years of the program, InTeGrate ramped up its offerings of 1-day workshops co-located with other professional societies, including the Ecological Society of America (Workshop #23 in Exhibit IV-1), Geological Society of America (#26), American Geophysical Union (Workshops #20, 21, 30 and 34), and Goldschmidt Conference (#33). These co-located short workshops offer the chance to entrain faculty who would probably not attend a specialized education conference or workshop.

The final years of the project brought robust offerings of workshops specifically targeting topics of concern to minorities underrepresented in geosciences and their allies (workshops #16, 24, 25, 29, 34, and 35 in Exhibit IV-1), including environmental justice and pan-African approaches to teaching about the Earth. This programming grew out of the efforts of the HBCU Working Group and IPs that had been working on diversity and inclusion.

Earth Educators’ Rendezvous

The InTeGrate leadership team and support staff began the InTeGrate project with extensive experience running 1-5 day face-to-face professional development workshops for faculty at institutions of higher education. The InTeGrate proposal envisioned that such workshops would be a major part of InTeGrate throughout, but that approximately mid-way through the project, the focus of the workshop program would shift from in-gathering of resources, ideas, and collaborators, towards dissemination of InTeGrate-created instructional materials and program-building models. In mid-2014,⁵ the leadership team made a drastic change in plans, perhaps the most substantive change from the proposal workplan. Rather than continue with small topical face-to-face workshops in the dissemination phase of the project, the team decided to put all their eggs into one big dissemination basket per year, originally called a “megaworkshop,” and eventually christened the “Earth Educators’ Rendezvous.” The rationale was that a megaworkshop could reach more people than a suite of small workshops, and that a megaworkshop could have the potential to become financially self-sufficient, whereas a program of small workshops would inevitably spin down when the InTeGrate grant concluded. Moreover, a megaworkshop would lead to

⁵ Evaluator’s notes and online leadership team notes from Leadership Team meeting on July 2014: https://serc.carleton.edu/integrate/workspace/july_2014_face-.html [Restricted access]

more mixing among people who might not otherwise meet, more exchange of ideas across sub-disciplines. In other words, it would result in more building of community.

The Rendezvous has run five times, in 2015, 2016, 2017, 2018, and 2019 with a sixth gathering scheduled for 2020 (Exhibit IV-2). The approximate number of attendees increased, from 315 in 2015, to 326 in 2016, then 342 in 2017, but then dropped back down to 233 in 2018. In 2019, attendance rebounded to approximately 301 attendees. The Rendezvous seems to be attracting a mixture of old and new attendees: 38% of the 2017 attendees, 49% of 2018 attendees, and 42% of 2019 attendees had attended a previous Rendezvous.⁶

Traveling Workshops⁷

The Traveling Workshop⁸ Program (TWP) brings national leaders in geoscience education to a campus or regional gathering for 1-2 days of intensive work around improving education about the Earth and environment. This program predated InTeGrate, having begun in 2009 under the auspices of the Building Strong Departments Program.⁹ InTeGrate supported the development of new elective modules with a stronger focus on environment and sustainability. More emphasis was placed on how departments could support ALL students; as part of this effort, the program recruited and trained a larger and more diverse group of workshop leaders.¹⁰

As of mid-semester Spring 2019, fifty-seven workshops had been held in the InTeGrate era, with more than 652 attendees, and seven more Traveling Workshops (TWs) were scheduled.¹¹ In their application, departments are able to choose from a variety of workshop themes designed to help them meet their course-, program-, and/or department-level goals. The mainstay of the Traveling Workshop program remains the “Building Stronger Geoscience and Environmental Science Departments & Programs” theme, chosen by 25 workshops, followed by Building Stronger Intro and Upper Division Courses, chosen by 10 workshops. An update of the more environmentally and societally oriented themes got off to a slow start, but has been building strength since Fall of 2017 (Exhibit IV-3.)

⁶ Excel spreadsheet received from Kristin O’Connell, SERC, 20 November 2019. Note that number of registrants and attendees are approximated, for reasons such as withdrawn registrations, registrants who did not show up to the event, and unregistered attendees. No formal attendance was taken at the Rendezvous, so no-shows are approximated by indirect measures such as not checking in to pick up name badges.

⁷ The Traveling Workshops component of the evaluation is based on a review of the program web materials, a telephone interview with program founder/leader Dallas Rhodes on 5 July 2018, emailed reflections from program founder/leader Diane Doser dated 12 June 2018, analysis of a spreadsheet prepared by SERC staff (tabulating institution, theme, electives, number of participants, and score on end-of-workshop evaluation survey), and websites from TWP Leadership team meetings and workshops.

⁸ Traveling Workshops Program: <https://nagt.org/nagt/profdev/twp/index.html>

⁹ Building Strong Departments Traveling Workshop Program visited 22 departments from 2009-2013. <https://serc.carleton.edu/departments/visitingworkshops/index.html>. Also: Ormand, C.J., et al. (2011). Building strong geoscience departments through the visiting workshop program: *EOS Transactions of the American Geophysical Union*, v. 91, Fall Meeting Supplement, Abstract ED42A-06. Slides at: https://d320goqmya1dw8.cloudfront.net/files/serc/ormand_et_al_2011.pdf

¹⁰ Traveling Workshop Facilitators: <https://www.nagt.org/nagt/profdev/twp/facilitators.html>. Decision to broaden the TWP to encompass the InTeGrate-related themes of broadening participation, workforce preparation, and connecting to sustainability and environmental issues was made at the TWP Leader Training Workshop at Carleton College, July 20-23, 2014, documented at: <https://nagt.org/nagt/profdev/twp-training2014/index.html> [Restricted access] Follow-on work at Leadership Training Workshops in 2015, 2017, and 2018 (<https://nagt.org/nagt/profdev/twp-training2015/index.html>, <https://nagt.org/nagt/profdev/twp-training2017/index.html> [Restricted access], and <https://nagt.org/nagt/profdev/twp-training2018/index.html> [Restricted access])

¹¹ Excel spreadsheet received from Mitchell Awalt, SERC, March 28, 2019.

Since 2015, evaluation surveys have been administered by the Traveling Workshop program at the end of each workshop. Participants indicate a high level of overall satisfaction with the workshops. The lowest rated TW scored 7.9 on a scale of 10 (where 10 indicates the highest satisfaction), and the mean score for 40 evaluated workshops was 9.0.¹² There is no systematic follow-up to find out to what extent the action plans developed during the workshop have been followed or what outcomes the planned actions may have led to.

Traveling Workshops have a strong potential to catalyze or invigorate local CoP's within or across departments on the same or geographically adjacent campuses, as participants work together on crafting an action plan and other collaborative activities. Relative to workshops where participants travel to a central location, the proximity of the TW participants should make continued interactions easier. However, there is no InTeGrate-era data bearing on how well the CoP-like sense of learning together and working together towards a shared goal persists after the workshop ends.¹³

Webinars¹⁴

Every webinar has an associated web page that lists the goals for the webinar. Although the first several goals vary from webinar to webinar, the last bullet was often “new colleagues engaged in this work,” thus making a public acknowledgment that weaving new threads into the tapestry of the InTeGrate fabric is an explicit goal of the webinar program.

The InTeGrate webinar series began in the Spring semester of 2015, early in project year 5, at a time when the first suite of materials had been published and were ready for dissemination. The earliest webinars (# 1-3 of Exhibit IV-4) pioneered a dissemination model of explaining what InTeGrate was, and then tried to interest and equip attendees for adopting InTeGrate materials and ideas. Webinars #5, 7, 8, 9, and 10 targeted an audience of instructional materials developers in need of coaching on practical matters such as Dealing with Copyright or with challenging aspects of the materials development rubric (systems thinking in webinar #7 and Metacognition in webinar #8). Beginning with webinar #11, a common InTeGrate webinar model featured presenters who were developers from several different modules, related through content area or pedagogical approach. By the middle of project year 5 (mid 2016), insights from the Implementation Programs began to play a more prominent role in the webinar program, for example webinars #19, 21, 22 were all IP focused. As new modules and courses were published, they also became the focus of webinars.

Over the last 2 years, the webinar series has had an increased emphasis on interdisciplinary and sustainability (see webinars # 44, 45, 55, 61, 63), and has ventured into diversity (#55), ethics (#59), environmental career prep (#60) and teacher prep (#57). Sister projects have reached out to the InTeGrate audience via the webinar program (GETSI: #48 and 49; Teaching Nanoscience: #64). During the last year

¹² *Ibid.*

¹³ The Traveling Workshop program was thoroughly evaluated back during its Building Strong Departments era: <https://serc.carleton.edu/NAGTWorkshops/departments/about/publications.html#reports>. In surveys and interviews with external evaluators, workshop participants spoke of stronger ties with faculty colleagues, for example, nine responses were coded as “learning more about how my colleagues think” and 24 were coded as “team approach” in an evaluation of the 2009-2010 workshops. See: https://d320goqmya1dw8.cloudfront.net/files/departments/about/summary_end_workshop_evaluation.pdf [Restricted access]

¹⁴ This aspect of the evaluation is informed by evaluator Kastens' participation in 19 webinars as an attendee, and two webinars as a presenter, plus by her review of the Workshops & Webinars section of the InTeGrate website (<https://serc.carleton.edu/integrate/workshops/index.html>). Kastens was a co-presenter for two InTeGrate webinars: Developing Students' Data Skills (October 2016) and Educating Skillful Visualizers (March 2018).

of the project, many webinars have been co-sponsored by AESS and NAGT (#60, 61, 62, 65, 66 and 67), working towards a support model independent of InTeGrate funding.

Most ITG webinars follow a set format. They begin with an introduction to the InTeGrate project, followed by several independent but interrelated presentations, interspersed with intervals for response to questions submitted via chat by the participants, followed by summary reflections from the presenters, announcements of coming webinars and a request to complete the evaluation survey. Most of the presenters are recruited from within the mid-level of the InTeGrate hierarchy (i.e. materials developers, materials adopters, IP leaders), with occasional appearances by members of the leadership team, Advisory Board, and outside experts. SERC provides an experienced facilitator for each webinar, who coaches the presenters towards best practices for web-based presentations.

HBCU Working Group

InTeGrate's Historically Black Colleges and Universities (HBCU) Working Group¹⁵ has consciously set out to build a community of educators committed to promoting education about the Earth and environment on HBCU campuses and in the communities that they serve. Under the leadership of Felicia Davis and Richard Gragg, the community now has 21 active members, representing 12 institutions of higher education. Three priority areas for the group are: teacher education, culturally responsible pedagogy, and interdisciplinary sustainability. The HBCU working group has catalyzed a robust set of convenings¹⁶ in support of this mission and these priority areas (see Exhibit IV-5). Although the convenings have different primary purposes and intended audiences, they all have as one goal to build a community of HBCU-affiliated educators and administrators who prioritize teaching and learning about the Earth and environment. This is seen as particularly important because so many HBCU's lack a geoscience or environmental science department, which could otherwise serve as the connection point for educators with such interests.

Implementation Programs

Implementation Programs have the potential to catalyze or strengthen local learning communities. Because IP's involve faculty who are geographically concentrated and may share some elements of institutional mission, it may be easier to create an enduring CoP within groups initially convened under an IP umbrella than groups convened through other mechanisms. For several IP's, creating a faculty community or network was an explicitly stated programmatic goal:

- The *California State University at Chico IP* had as one of their two program goals, "Develop a community of faculty who collaboratively incorporate InTeGrate resources in pathway courses and work together in peer-based professional development."¹⁷ A "pathway" at CSU-Chico comprises a coordinated set of courses a student can take that collectively satisfy the university's GenEd requirements. The pathway system was instituted in 2012, and there was an existing Sustainability Pathway, but the faculty did not coordinate their teaching, and some had not even met each other. During the IP grant, pathway faculty participated in multi-day summer workshops, observed each

¹⁵ Home page for HBCU working group: https://serc.carleton.edu/integrate/about/hbcu_working_group.html

¹⁶ Web documents plus interview with Felicia Davis and Richard Gragg III at the Earth Educators Rendezvous, July 20, 2018. Also, Archer, R., Davis, F., Ebanks, S. C., & Gragg, R. D. S., III. (2019). HBCU's broadening participation in Geosciences (a journey through InTeGrate). In D. C. Gosselin, A. E. Egger & J. Taber (Eds.), *Interdisciplinary Teaching about Earth and the Environment for a Sustainable Future*. Switzerland: Springer, pp. 361-378. Also, InTeGrate reporting page of R. Gragg: <https://serc.carleton.edu/integrate/HBCUplan/gragg.html> (restricted access). Also 2018 annual report of the HBCU working group:

https://serc.carleton.edu/admin/private_download.php?file_id=249905 [Restricted access]

¹⁷ CSU-Chio IP> Improving Programs:

<https://serc.carleton.edu/integrate/programs/implementation/chico/program.html#goal2>

others' classes frequently, and collaboratively reviewed student learning data. University administrators and pathway coordinators attended some of their meetings. The IP pathway group describes themselves as an FLP (Faculty Learning Community.)

- *The University of South Dakota IP* had as one of their three program goals “Increase faculty knowledge and awareness of earth science and sustainability through networking.” As part of the evaluation of this goal, each participating faculty member filled out a web-based faculty journal,¹⁸ which asked (among many other things), “Who did you work with when adding this material [sustainability activities and/or learning experiences] and what was the nature of those collaborations?” Only one of the nine available faculty journals indicated a connection with other faculty as they added sustainability materials into their courses. Most respondents left this question blank. IP activities that had the potential to strengthen community/network included a workshop for participating faculty with a river trip, monthly brown-bag meetings to exchange ideas, and a final culminating workshop at the end of the implementation. PI’s state that “the Sustainable Rivers program created a ‘river community’ on campus that has led to other collaborations, including grant proposals and pedagogy.”¹⁹

Online virtual communities

InTeGrate has also experimented with online virtual communities of interest. On the cover page of each module or course, there is a link to “Join the Community.” Towards the bottom of the web page associated with most InTeGrate webinars is a link to “Join the [relevant module or topic] Teaching Discussion,” which directs participants to a discussion board with the option to join an associated email list, if there is one. Faculty state that this is something they want, and as of July 2018, 1044 individuals had joined these virtual communities of interest.²⁰ As of June 12, 2018, there were 38 online interest groups associated with modules or courses, plus one topical special interest group.²¹ However, most of the online discussion areas have little to no traffic (Exhibit IV-6). The most active group (Humans’ Dependence on Earth’s Mineral Resources) had accrued only 11 messages. There are some interesting queries and suggestions raised in individual posts,²² but none of the groups has achieved critical mass or become a regular part of members’ professional life.²³

The project has tried various approaches to catalyze discussion,²⁴ including encouraging the module developers to engage online with the community, assigning a staff person to engage communities online, running webinars targeted to specific online communities, and associating discussion topics with time of

¹⁸ USD IP> Faculty Reports:
<https://serc.carleton.edu/integrate/programs/implementation/southdakota/faculty/index.html> (pages linked within are restricted access)

¹⁹ InTeGrate Program Models>Univ South Dakota>Improving Programs:
<https://serc.carleton.edu/integrate/programs/implementation/southdakota/program.html>

²⁰ From Kathryn Sheriff, SERC staff, Oct. 17, 2018.

²¹ Join the InTeGrate Community: <https://serc.carleton.edu/integrate/participate/communities.html>

²² Individual posts have used the online community lists to point out a potential error in a module (which developers responded to and fixed), to announce an update to a module, and to discuss adaptation for online use.

²³ A June 13, 2019 spot check of every 5th online community listed on the Join the Community website showed little improvement: only three new messages found.

²⁴ Personal communication from Cathy Manduca and Ellen Iverson, Sept. 2018, evaluation meeting, Carleton College.

year (e.g. start of term.) This should not be too surprising or disappointing, in that other attempts to establish purely online communities of education practitioners have also struggled.²⁵

Sub-claim 3B: The groups of people brought together by InTeGrate support each other in improving their educational practice by sharing and exchanging insights, experiences, resources, and best practices.

Workshops as venues for sharing and exchanging

The workshop design and infrastructure begun by *On The Cutting Edge* and adapted by InTeGrate had features that were intended to supercharge the community process of “sharing and exchanging of insights, experiences, resources, and best practices.” Rather than let a normal informal collaborative exchange percolate naturally and slowly, *Cutting Edge* and InTeGrate workshops had specific activities designed to mine the insight-containing ore from where it was thinly dispersed across the minds, hard-drives, shelves, and filing cabinets of the workshop attendees. Other processes were put in place to refine the ore to extract the insights, including follow-up work by skilled craftsmen (conveners and SERC staff) to shape the refined ore into lovely and practical products. Finally, a display showcase (website) presented the refined products in a way that would be attractive to customers/users.

Partnership workshops, co-sponsored with the older *On the Cutting Edge* program, introduced attendees to the InTeGrate project and sought to recruit allies who might be interested becoming a part of InTeGrate’s materials development program. Many of these workshops had specific activities in which small groups of attendees brainstormed about an instructional module they would like to develop. Some of these workshop discussions matured into full-fledged InTeGrate Materials Development teams; examples are provided under Sub-claim 3C: “*New knowledge & resources emerging from workshops.*”

The workshops labeled as “in-gathering workshops” in Exhibit IV-1 were explicitly designed to surface, capture, and organize ideas and resources related to specific challenges that InTeGrate was undertaking: e.g. teaching geoscientific habits of mind (Workshop #3), teaching about the Earth in the context of societal problems (# 4, 6, 11), expanding teaching about the Earth to wider audiences (#5, 8, 9, 16), teaching with credible authentic Earth Science data (#13), and building entire programs rather than individual courses (#1). Many of the in-gathered ideas and resources were massaged by project staff into public websites, designed to bring the insights to those who had not attended the workshops, for example:

- Workshop #6, Teaching Environmental Justice: Interdisciplinary Approaches, gave rise to website *Environmental Justice in the Context of Sustainability*.²⁶
- Workshop #8, Geosciences and the 21st Century Workforce: Considering Undergraduate Programs in the Context of Changing Employment Opportunities, gave rise to the website *The Workforce for a Sustainable Future*.²⁷

²⁵ Barab, S. A., MaKinster, J. G., Moore, J. A., Cunningham, D. J., & The ILF Design Team. (2001). Designing and building an online community: The struggle to support sociability in the Inquiry Learning Forum. *Educational Technology Research & Development*, 49(4), pp. 71-96. Jurist Levy, A. (2016). Just-in-time professional development: The Active Physics Community. In C. Dede & A. Eisenkraft (Eds.), *Teacher learning in the digital age*. Cambridge, MA: Harvard Education Publishing Group, pp. 109-126.

²⁶ Environmental Justice in the Context of Sustainability: https://serc.carleton.edu/integrate/teaching_materials/themes/societal_justice/EJ.html. A publication also emerged from this workshop: Darby, Kate J., Atchison, Christopher I., (2014). Environmental Justice: insights from an interdisciplinary instructional workshop, *Journal of Environmental Studies and Sciences*, 4(4), pp 288-293.

²⁷ The Workforce for a Sustainable Future: https://serc.carleton.edu/integrate/programs/workforceprep/workforce_overview.html

- Workshop #12, Teaching Geoethics across the Curriculum, gave rise to the website *Geoethics in the Context of Sustainability*.²⁸

The synoptic web pages that emerged from the in-gathering process provide a convenient, centralized, open access source for information that would otherwise be difficult for faculty members to obtain. There is no evaluation data on the extent to which these synoptic web pages have played a role in changing teaching practice or informing the development of programs and departments.

Webinar series

Although the webinars feature InTeGrate-involved presenters and use mostly InTeGrate-based examples, in some cases they serve as a forum for spreading research-based best practices that draw from a wider knowledge base. In these cases, the InTeGrate-involved presenters have scoured the education literature and their own networks for solutions to their own local challenges. They then use the trading zone provided by the InTeGrate webinar to pass along insights in a format that combines personal narrative (what worked for us) with attachment points into the wider education literature. For example:

- *Ways to Support all Students*, presented November 13, 2017, by Diane Doser and Joshua Villalobos, draws on the UTEP IP experience plus the work of Ibarra (2001) on “multi-contextual student populations” and the “capacity-engagement-continuity” model of Jolly et al. (2004).²⁹

In addition, webinars brought instructional materials from other curriculum development projects into the InTeGrate community, opening up the possibility for cross-fertilization of ideas picked up from other projects and outside collaborators. Webinars that had the potential to catalyze cross-project interactions include:³⁰

- *Using Model-based Reasoning and Experiential Learning to Understand and Improve Sustainability in a Campus Food System*, presented Sept 12, 2017, by leaders from the EMBeRS project (Employing Model-based Reasoning in Socio-Environmental Synthesis).
- *Addressing Earthquake Hazards with LiDAR, GPS, and InSAR in Uppper-level Undergraduate Courses*, presented April 13, 2017, by leaders from the GETSI project (GEodesy Tools for Societal Issues).
- *Incorporating Environmental Data-Driven Inquiry and Exploration into your Course*, presented March 30, 2017, by leaders from the EDDIE project (Environmental Data-Driven Inquiry & Exploration).

Earth Educators’ Rendezvous as venue and catalyst for sharing and exchanging

The format of the EER is designed to maximize opportunities for collegial interactions and for leadership growth. Mornings are devoted to 3-day or 2-day workshops, for which one must sign up in advance, and which provide opportunity for sustained interaction around a topic of shared interest. Some of these workshops are convened by other funded education projects: such co-location serves to advance the work of those programs, disseminate findings to the broader community, and weave together

²⁸ Geoethics in the Context of Sustainability:

https://serc.carleton.edu/integrate/teaching_materials/themes/societal_justice/geoethics.html

²⁹ Jolly, E. J., Campbell, P. B., & Perlman, L. (2004). Engagement, Capacity and Continuity: A trilogy for student success. Ibarra, R. (2009). Context diversity: Reframing higher education in the 21st century.

<https://compact.org/resource-posts/context-diversity-reframing-higher-education-in-the-21st-century/>

³⁰ https://serc.carleton.edu/integrate/workshops/webinars/2017_2018/itg_food_security/index.html

https://serc.carleton.edu/integrate/workshops/webinars/2016_2017/earthquake_hazards/index.html

https://serc.carleton.edu/integrate/workshops/webinars/2016_2017/env_data/index.html

participants and leadership of various geo-ed projects.³¹ EER afternoons offer mini-workshops, oral presentations, posters, and round table discussions. Beginning in 2016, the Rendezvous program added Teaching Demos,³² in which a presenter demonstrates an active learning lesson that could be “take homes” for attendees to use in their own teaching. In 2018, the EER added a Share-a-Thon³³ in which presenters shared their favorite activities or lessons with colleagues in a small group format. In addition, the EER organizers encourage interest groups, working groups, and project teams to meet at the Rendezvous and facilitates such side meetings by through scheduling and venues.³⁴ Serving as the venue for working groups, interest groups, project team meetings, and workshops convened by other funded projects has also been an effective mechanism to bring new people to the Rendezvous and thus into the InTeGrate community.³⁵

During the 2015 Earth Educators Rendezvous, InTeGrate evaluator Kim Kastens engaged 94 conference attendees (31%) in “lightning interviews” designed to probe to what extent the conference was helping to build new collaborative and collegial connections in the geoscience education community.³⁶ Ninety-two percent of respondents replied yes when asked “Here at the Rendezvous, have you met anyone that you would like to collaborate with, continue to be in touch with, or work with after the meeting?” The affirmative responders were then asked “What would be the nature of the ongoing interaction or work that you had in mind?” Responses were coded using emergent coding categories (Exhibit IV-7). By far the most common form of ongoing interaction desired and anticipated was various kinds of exchange of ideas and/or resources around teaching (44% of respondents), followed by sharing ideas and/or resources around education research. These responses suggest that the EER may be opening up new pathways for collaborative exchange of resources and/or ideas.

During lightning interviews at the 2016 Rendezvous, 30% of the attendees were asked for an example of something that they had gotten out of the meeting that they expect to be able to use in their work, and then for an example of something they had been able to give back to the Rendezvous that other individuals

³¹ Examples of other NSF funded education projects scheduling their work as Rendezvous workshops: Heads & Chairs Workshop: Future of Undergraduate Geoscience Education: https://serc.carleton.edu/earth_rendezvous/2017/program/morning_workshops/w5/index.html. Synthesizing Geoscience Education Research: Where are We? What is the Path Forward? https://serc.carleton.edu/earth_rendezvous/2015/morning_workshops/w3/index.html

³² e.g. https://serc.carleton.edu/earth_rendezvous/2016/program/demos/index.html

³³ e.g. https://serc.carleton.edu/earth_rendezvous/2018/program/share-a-thon/index.html

³⁴ Schedule for working group meetings at the 2018 Rendezvous is here: https://serc.carleton.edu/earth_rendezvous/2018/program/workinggroups.html. There were 14 such meetings, involving 7 groups.

³⁵ Monica Bruckner, SERC, personal communication September 2019. For instance, the 2017, 2018, and 2019 Rendezvous included convenings of the HBCU working group and the 2019 Rendezvous included a convening of a GER writing working group. Both of these groups had members who were first-time Rendezvous attendees. Additionally, the Rendezvous held workshops in partnership with projects such as GETSI, OOI, GEODE, MATLAB, among others, which attracted first-time attendees in some cases. In addition, in 2018, the Rendezvous attracted participants from a concurrent AMS gathering, offering an afternoon mini-workshop that was led by one of the AMS representatives (https://serc.carleton.edu/earth_rendezvous/2018/program/afternoon_workshops/w8.html). Holistic assessment based on processing of attendance data, discussion with registrants, evaluation survey responses across five years of Rendezvous.

³⁶ Further detail in Kastens, K.A. (2015). Weaving new threads into the GeoEd community of practice: Report on interviews at the 2015 Earth Educators' Rendezvous, unpublished InTeGrate report. Available online at https://d320goqmya1dw8.cloudfront.net/files/integrate/about/2015_eer_interviews.pdf

would be able to use in *their* work.³⁷ These responses were not coded, but the interviewer noted that many of the “giving” examples were what might be called “micro-contributions,” such as sharing ideas during a hands-on teaching demo, or pointing people towards useful resources. In contrast to a more formal conference where the available roles may be just audience member, presenter, and question-asker, the highly interactive format of the Rendezvous offers a myriad of opportunities for micro-contributions to emerge. Micro-contributions offer an easy opportunity for non-contributors to transition into contributors, and thus may be a mechanism for moving individuals from the periphery towards the center of the community of practice.

After providing examples of something they had given and something they had gotten from the Rendezvous, 2016 lightning interview respondents were asked about the ratio, the balance, they had experienced between giving and getting, and whether they were satisfied with that balance. Responses are consistent with the claim that the Rendezvous is functioning as an effective venue for reciprocal exchange of resources, ideas and information (Exhibit IV-8). Every respondent reported both giving and getting. A 50:50 get:give balance was the single most common answer, and most participants reported getting more than they gave. Whatever balance they reported, the vast majority were satisfied with the balance they had experienced.

Relative newcomers to the GeoEd community (defined as those who had attended zero previous SERC-supported workshops) had a high get:give ratio. As exposure to the GeoEd community increases, the reported ratio shifts towards more giving, less getting (Exhibit IV-9). A parallel pattern is seen in comparing leaders to non-leaders. These data are consistent with a dynamic in which newcomers benefit from receiving resources, insights, experiences and best practices from the community and then later increasingly serve as sources of these benefits. One respondent, at the extreme 90:10 give:get end of the continuum, expressed weariness and frustration at giving so much and getting so little. But the rarity of this response, and the abundance of heavy givers, suggests that the GeoEd community has managed to establish a viable trading zone for the exchange of educational goods and services.

Implementation programs

Individual IP team members attested to their IP’s value as a venue for sharing and exchanging insights, experiences, resources, and best practices in both their published Faculty Reflections and in interviews conducted by external evaluators at the end of the project. A few examples:³⁸

- [Another IP team member] provided a wealth of information about [our topic]. He was able to inspire me to learn more ... and in turn ignite that same curiosity in the hearts and minds of my learners.
- This experience has opened up networking opportunities, and I got to know the other participating faculty better by working on this project together, and I know if I ever need anything additional I could reach out and ask for assistance.
- ... a geoscientist and ... a political scientist had offices in adjacent buildings for years, but had not worked together on their teaching before. The development of the... InTeGrate program model

³⁷ Further details in Kastens, K. A. (2016). Attendees’ perceived balance between “getting” and “giving” at the 2016 Earth Educators’ Rendezvous: Results from lightning interviews. Online at https://d32ogoqmya1dw8.cloudfront.net/files/integrate/about/lightning_interviews_report_from.pdf. Also: Kastens, K. A. (2018). Weaving new threads into the Geoscience Community of Practice: Insights from Lightning Interviews at the EER 2015, 2016, 2017. Poster presented at EER 2018, online at: https://d32ogoqmya1dw8.cloudfront.net/files/earth_rendezvous/2018/program/posters/wednesday/kastens_eer_2018_poster.pdf.

³⁸ Sources: <https://serc.carleton.edu/integrate/programs/implementation/southdakota/reflections.html> and <https://serc.carleton.edu/integrate/programs/implementation/MTSU/program.html>.

proposal led them to discover common goals... Dr. L. was interested in adding a significant amount of Earth Science content to her American Public Policy Course, which Dr. A. was interested in facilitating. This interaction caused them both to engage in new material and work together.

In addition, the survey administered to IP team members contained one question probing the IP experience as a means for fostering interactions and collaboration: “The design of the InTeGrate program activities aims to foster greater collaboration among faculty within and across institutions. In what ways has your experience with the InTeGrate implementation program influenced your interactions related to teaching?” For an array of five types of potential collaboration/engagement (plus “other”), respondents could choose from: “Not applicable to my professional situation,” “Does not influence me in this way,” “True for me to some extent,” or “True for me to a great extent.” Exhibit IV-10³⁹ shows what percentage of respondents chose one of the affirmative responses: “some extent” or “a great extent.” The overwhelming majority (87.4%) of the respondents gave an affirmative response for at least one of the offered forms of engagement/collaboration. The most frequently indicated (67-70%) forms of collaboration/engagement that the InTeGrate IP experience was said to have influenced were: “ways in which I engage with other departments about teaching” and “ways in which I engage with others at my institution.” The least frequently indicated (44%) was “ways in which engage beyond my institution.”

These qualitative and quantitative responses are compatible with an interpretation that, for many participants, the IP experience wove new threads into their collaborative network within their institution, and that these new connections were around teaching.

Sub-claim 3C: Moreover, the groups of people brought together by InTeGrate sometimes invent new practices or create new knowledge.

In their model of what makes the Geoscience Education community of practice effective, Kastens & Manduca (2017) emphasize the importance of community members co-creating useful tools and resources. This need not be a universal aspect of communities of practice, but in the GeoEd community, Kastens & Manduca see co-creating activities as serving two important roles: contributing to a warm collegial feeling of acceptance and accomplishment that drives an effective reinforcing feedback loop, and creating useful products that build up the community’s capacity for the practice.

New knowledge & resources created at workshops

Almost all InTeGrate workshops involve micro-opportunities for the co-creations of small resources or tools. The co-created products are intended to be useful to the workshop attendees, and ideally to the broader community. For example, at the early in-gathering workshop on Systems, Society and the Geosciences (July 2012), participants worked in small groups to articulate the key concepts that students in various disciplines should learn about sustainability.⁴⁰ At an early in-gathering workshop on Programs that Bring Together Geoscience and Sustainability, participants worked in small groups to articulate the strengths, challenges, and opportunities of such programs. Post-workshop, this work was refined into a public synthesis product.⁴¹

Recruitment materials for the workshops in the first half of the project forthrightly stated: “An important outcome from this workshop will be to identify opportunities where new curricular materials

³⁹ Data from Excel file “IP_faculty survey Q11” from K. Sheriff, SERC, graph by Kim Kastens.

⁴⁰ Key concepts for teaching sustainability:
https://serc.carleton.edu/integrate/workshops/sustainability2012/key_concepts.html

⁴¹ Workshop Synthesis: Programs that Bring Together Geoscience and Sustainability.
<https://serc.carleton.edu/integrate/workshops/programs2012/synthesis.html>

will have a major impact on integrating geosciences into the teaching of sustainability” or “to identify opportunities where new interdisciplinary curricular materials will have a major impact on integrating geosciences into the teaching of engineering.”⁴² A typical day-2 activity at these early workshops was that groups worked together to develop proposals for new courses or modules on the workshop theme.

Some of these workshop conversations later matured into Materials Development teams. Examples include:

- At the June 2012 workshop on *Teaching Methods of Geoscience* workshop, Jim Ebert, Scott Linneman, and Jeff Thomas worked together on early ideas for what eventually became the *Exploring Geoscience Methods* module.⁴³
- From the April 2013 workshop on *Teaching Environmental Justice: Interdisciplinary Approaches*, emerged the team of Kate Darby, Lisa Phillips, and Michael Phillips, who co-developed the module *Mapping the Environment with Sensory Perception*, which they piloted in an Environmental Justice course, an English composition class, and an environmental geology course.⁴⁴
- From the May 2014 workshop on *Teaching about Risks & Resilience: Sea Level Rise, Flooding, and Earthquakes*, arose the module on *Major Storms and Community Resilience*, with workshop participants Lisa Doner, Patricia Stapleton, and Lorraine Motola as co-developers.⁴⁵

Instructional materials development teams

Faculty teams comprising at least three faculty from multiple institutions collaborated on designing, building and testing instructional modules or courses. The powerful role that this collaborative effort had on building collegial ties across institutions and disciplines was documented in Sub-claim1C: “*Impact on faculty.*”

Assessments and assessment procedures

The Assessment Team was assembled, by application, from among geoscience educators with assessment and evaluation experience. Over 5 years of activity, they co-created many ambitious products, in some cases working with the Leadership Team, external evaluation team, and/or SERC technical staff, including:

- The Materials Development and Refinement Rubric
- The Geoscience Literacy Exam (GLE), both long and short versions
- Essay questions for Systems Thinking and Interdisciplinary Problem Solving
- Rubrics for scoring both essay questions

⁴² Sustainability quote from: <https://serc.carleton.edu/integrate/workshops/sustainability2012/index.html>

Engineering quote from: <https://serc.carleton.edu/integrate/workshops/engineering2013/index.html>

⁴³ Example documented in email from Anne Egger, June 17, 2019. Teaching the Methods of Geoscience workshop: <https://serc.carleton.edu/integrate/workshops/methods2012/index.html>. Exploring Geoscience Methods module: https://serc.carleton.edu/integrate/teaching_materials/geosci_methods/index.html

⁴⁴ Workshop website: <https://serc.carleton.edu/integrate/workshops/envirojustice2013/index.html>. Module website: https://serc.carleton.edu/integrate/teaching_materials/map_sense/index.html. Instructor stories for this module: https://serc.carleton.edu/integrate/teaching_materials/map_sense/instructor_stories.html.

⁴⁵ Teaching about Risk & Resilience workshop: https://serc.carleton.edu/integrate/workshops/risk_resilience/index.html. Major storms & Community Resilience module: https://serc.carleton.edu/integrate/teaching_materials/storm_resilience/index.html

- A collaborative system for scoring essay questions
- Several iterations of collaborative systems for scoring formative and summative embedded assessments.

Collectively, these elements aggregate to more than the sum of their parts. Together, they comprise a system for conducting collaborative education research in a distributed fashion in a large number of geographically distributed classrooms at a variety of institution types, as discussed in Sub-claim 1D: *Assessment System*.

Sub-claim 3D: These convenings contribute to a feeling of being part of a mutually-beneficial community of shared interest.

Evidence that InTeGrate’s convenings contributed to feeling a part of a community of shared interests comes from three sources: short interviews done with participants at the Earth Educators’ Rendezvous, an analysis of the NAGT national survey of Geoscience Faculty, and longer telephone interviews done in the final year of the project with 51 faculty who had been involved in InTeGrate.

Lightning interviews at EER

At the 2017 Earth Educators’ Rendezvous, evaluator Kastens engaged 113 attendees (31% of total attendance) in face-to-face “lightning interviews” which asked for short words or phrases to characterize how the respondent felt about their experience at the Rendezvous.⁴⁶ Responses were coded and tallied. The abundance of responses coded as “community,” “networking,” or “collaboration” in these unguided responses (Exhibit IV-11) suggest that attendees were finding the Rendezvous to be an effective venue in which to connect with colleagues.

Many of the “Community” responses have a strong emotional valence of belonging and feeling welcome. Examples include: “...my people are here,” “Validated,” “I am not alone,” “Welcoming,” “Friendly,” “Camaraderie,” “Finding like-minded individuals,” “Friendship,” “People are caring, committed and compassionate.” The “Collaboration” responses have a more pragmatic, less affective, tone, e.g. “Collaboration, met someone in the same field, just spent 45 minutes talking.” The “Networking” responses foreground connections that may be of practical use in the future, e.g. “Making professionally key networking connections.” All three coding categories convey that connection to colleagues/friends was prominent in respondents’ felt experience of the Rendezvous.

Telephone interviews

During the last year of the project, evaluators Debra Bragg and Lia Wetzstein of the University of Washington in Seattle conducted telephone interviews with 51 InTeGrate-involved faculty.⁴⁷ Interviewees were purposefully selected at three different levels of InTeGrate involvement: Materials Developers, Mentored faculty (involved in either IP’s or the QUBES program), and Unmentored faculty (attended webinars or workshops, but did not have sustained mentoring around their use of InTeGrate materials and

⁴⁶ Kastens, K. A. (2017). Weaving new threads into the Geoscience Community of Practice: Insights from lightning interviews at the EER 2015, 2016 and 2017. Poster presented at the Earth Educators Rendezvous, Lawrence, KS. https://d320goqmya1dw8.cloudfront.net/files/earth_rendezvous/2018/program/posters/wednesday/kastens_eer_2018_poster.pdf

⁴⁷ Wetzstein, L., Kovacich, K., & Bragg, D. (2017). InTeGrate Faculty Study: Community College Research Initiatives: University of Washington. Unpublished report prepared for the Science Education Resource Center, available upon request. Also, Iverson, E. R., & Wetzstein, L. (In press). Connecting learning about the earth to societal issues: Downstream effects on faculty teaching. In J. Ostrow (Ed.), *Teaching about Sustainability across Higher Education Coursework, New Directions for Teaching and Learning*, No. 161. San Francisco: Jossey-Bass.

approaches). “What is the role of the InTeGrate project in fostering teaching community participation and interactions?” was one of three guiding questions for the interview study.

At all three levels of InTeGrate involvement, there was a spectrum of responses. The extreme spectrum ranged from “no change in teaching and learning community” all the way to “life changing.” Towards the life-changing end of the continuum, comments included:

- “...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” (from a Materials Developer).
- “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” (from a Materials Developer).
- “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” (from a member of the Mentored Faculty group).

NAGT national survey of geoscience faculty

For the 2016 administration of the NAGT national survey of geoscience faculty,⁴⁸ several new items were added that probe the respondent’s sense of affiliation with a community of geoscience educators and how they interact with this community. The new items are:

- Q40 - To what extent do you consider yourself part of a community of geoscience educators that shares your goals, philosophy, and values for geoscience education?
- Q41 - To what extent do interactions with this community help you become a better educator?
- Q42_x: In which of the following ways do you interact with this community? [7 choices]
- Q43_x: How have your interactions with this community influenced you? [4 choices]

Using data from the SERC account-holder database, survey respondents were classified by their degree of InTeGrate involvement as follows:

- No ITG record (n=2201)
- ITG Asynchronous Participant (n=166): members of this group have a record in the ITG database, but have no record of having attended a webinar, workshop, or other event. Such a person may have joined an interest group, downloaded materials from the ITG teacher stash, or had a similarly minor interaction that did not involve real time interaction with community members.
- ITG Synchronous Participant (n=187): members of this group have been a participant, presenter, or leader of a workshop or webinar.
- ITG Super-Participant (n=61): members of this group have had sustained and influential involvement in InTeGrate, for example as a member of the Leadership Team, an Implementation Team leader, or a module developer.

Responses to the “community” survey questions show that respondents who had had a higher degree of involvement in InTeGrate reported a stronger sense of affiliation with “a community of geoscience educators” (Exhibit IV-12), and were more likely to say that interactions with this community helped them

⁴⁸ Overview of survey effort: National Geoscience Faculty Survey: https://serc.carleton.edu/NAGTWorkshops/CE_geo_survey/index.html. Link to survey items for all years: *On the Cutting Edge* Evaluation: <https://serc.carleton.edu/NAGTWorkshops/about/evaluation.html>

to become a better educator (Exhibit IV-13). The more extensive a respondent's involvement with InTeGrate, the more likely they were to report engaging in each of six different forms of involvement with the community (seeking people to talk to who have experience relevant to my situation, providing assets or resources to other community members, discussing developments in geoscience education, finding collaborators for a new project, and engaging in deep two-way conversation in support of our educational work; Exhibit IV-14). And the more extensive their InTeGrate involvement, the more likely they were to report that their interactions with this community influenced them in each of three positive ways (renewed my enthusiasm, built my confidence, introduced me to new professional opportunities; Exhibit IV-15).

Note that this cluster of associations alone is not proof that participating in InTeGrate-enabled convenings and connections *causes* individuals to feel a sense of community affiliation and engage in community enabled interactions. Even among the people with no ITG record, there are still 15% of respondents who selected "to a great extent" on survey Q40, and of course there are many excellent non-InTeGrate Geoscience Education convenings and opportunities for interaction. It seems most likely that causality runs in both directions, in a self-reinforcing virtuous spiral: individuals who value a sense of GeoEd community are more likely to come to an InTeGrate event in the first place; and then InTeGrate events work to strengthen that feeling of community engagement among the people who are there.

Sub-claim 3E: The national community of practice and some of the local or regional communities of practice are structured so as to be able to carry on after the end of the NSF grant.

Earth Educators' Rendezvous

The Earth Educators' Rendezvous (EER) was founded as a joint endeavor of InTeGrate and the National Association of Geoscience Teachers (NAGT), with the intention that it would become fully run by NAGT over time. The first EER, in 2015, had a shared funding and leadership model, with InTeGrate contributing 20% of the cost. By 2017, leadership and financial responsibility had been transferred completely to NAGT. Costs are kept low by using university locales and volunteer leadership. Participants pay to attend, some personally, some with institutional funds, some with grant funds. Commercial sponsors have been attracted to underwrite a few high-visibility events such as keynote talks, and professional societies contribute to the overall cost of the event. The transfer of responsibility was facilitated by the co-location of the InTeGrate headquarters and the NAGT Executive Office both at SERC, with some shared staff. The business and leadership model appears to be viable.

The drop in attendance from the 300's in 2015/2016/2017 to approximately 233 in 2018 (Exhibit IV-2) was worrisome, but attendance rebounded back to approximately 301 in 2019. Discussion with Rendezvous leaders and support staff suggest that to maintain desirable attendance levels in the future, it will be important to continue to attract co-located project meetings and workshops sponsored by funded geo-ed projects that subsidize travel and/or registration, to avoid states with travel bans, and to favor locations that are easy to get to and desirable for vacation and/or field trips. The scheduled venue for 2020 (Stanford University) is in a state with a high concentration of Earth educators and strong potential for field trips.

HBCU Working Group

The InTeGrate HBCU Working Group has taken decisive steps to become the HBCU Geoscience Working Group, an enduring entity independent from InTeGrate. At their workshop during the 2018 Rendezvous, they laid out a potential organizational structure with leadership and committee structure, and provision for representation from each institution/organization.⁴⁹ They are weaving their activities and priorities into existing professional networks, as evidenced by a 2017 agreement among the HBCU

⁴⁹ https://serc.carleton.edu/integrate/HBCUplan/hbcu_geosciences_working_group.html [Restricted access]

Working Group, the National Association of Black Geoscientists, and the National Technical Association, to join forces in moving an HBCU geoscience agenda.⁵⁰ In 2018, The National Technical Association, the oldest black STEM-focused organization, established a formal relationship with the HBCU Geoscience Working Group as its permanent organizational home.⁵¹

Building on the work of the InTeGrate-era HBCU Working Group, HBCU members S. Ebanks, F. Davis, and R. Archer have submitted a successful GeoPATHS proposal. *GP-Impact: Expanding HBCU Pathways to Geoscience Education* has the ultimate goal of improving African-American representation in the geosciences, through the vehicle of improving the geoscience component of middle school teacher preparation curriculum and professional development at five HBCU's that have strong teacher preparation and/or geoscience programs. The proposed project would develop an evaluation tool to identify gaps and opportunities in existing programs, and develop culturally-relevant, place-based pedagogical approaches to enhance instruction at the participating institutions. Collaboration between individuals and across institutions is a central element of the proposed work, facilitated by a shared vision, established collegial ties, and use of the SERCkit suite of digital collaboration tools. In addition to meeting the immediate teacher prep and PD goals, funding of this project would allow the HBCU Geoscience Working group to continue to develop as a vibrant, effective CoP.

Traveling Workshops

The Traveling Workshop Program is run by NAGT and is incorporated into its annual budget. As a legacy of the InTeGrate era, the cadre of workshop leaders is larger and more diverse. The TWP experience is now relevant to a wider range of types of departments and programs, including those that wish to work on sustainability education, teacher prep, or broadening participation.

The TWP seems in a strong position, financially and organizationally, to carry on after InTeGrate sunsets. Groups that wish to host a traveling workshop provide the facilities and cover the leaders' expenses, plus pay a \$2,000 fee to NAGT that goes towards leaders' honoraria, web costs, and program management.⁵² Leaders' base salary is covered by their home institutions, and thus the operating cost of the program is lean. A Traveling Workshop Management Team was formed in Spring of 2018, chaired by a veteran TWP workshop leader.⁵³ With this lean structure and the InTeGrate era innovations in place, the program is well situated to continue in steady state mode, but could face challenges if the teaching materials need a major update or if veteran leaders depart.

Small face-to-face workshops

There is no plan to continue with a coordinated program of small (a few dozen participants), free-standing, face-to-face topical workshops, of the sort perfected by *On the Cutting Edge* and continued through the early years of InTeGrate. The Earth Educators' Rendezvous and webinars are thought to be a more sustainable way of achieving the professional development goals previously targeted by small workshops.

However, there are now dozens of experienced workshop leaders in the GeoEd community who have the skill set and credibility to propose workshops on topics of interest to them, and so there may well be one-off workshops organized by individuals or small groups, perhaps in association with other professional

⁵⁰ Agreement forged at 2017 NTA Conference according to 2017 Annual Report of HBCU Working Group: https://serc.carleton.edu/integrate/HBCUplan/annual_report.html [Restricted access]

⁵¹ HBCU Working Group 2018 Annual Report: https://serc.carleton.edu/admin/private_download.php?file_id=249905 [Restricted access]

⁵² Traveling Workshop Program>Workshop Synopsis> Expectations if Selected. https://nagt.org/nagt/profdev/twp/dept_process.html#expectations

⁵³ Telephone interview with Dallas Rhodes, July 8, 2018.

gatherings. Models would be the 2-day “Educating Skillful Visualizers” workshop conducted before the 2017 Gordon Research Conference on Visualization in Education and Science,⁵⁴ and the K-12 Educator Program in association with the 2018 Goldschmidt Conference,⁵⁵ both co-convened by members of the InTeGrate leadership team.

Local CoP’s emerging from Implementation Programs

Several of the Implementation Programs secured institutional or other funding to keep some of their activities going after their InTeGrate grant expired. Since most IP groups had geographic proximity and/or share institutional affiliations, IP faculty should find it relatively easy to maintain their collaborative ties-- if they find it rewarding to do so.

- The CSU-Chico IP had “Develop a community of faculty...” as an explicit program goal and described their IP team as an FLC (Faculty Learning Community). As they wrote up their final IP program description in Spring of 2017,⁵⁶ they anticipated two potential directions for future growth: bringing additional pathway faculty into their FLC, and offering their experience as a model to faculty groups teaching in CSU-Chico’s other Gen Ed pathways.
- The Savannah State University IP had “Collaboration” in its title (“Collaborate to Heighten Awareness, Rejuvenate, and Train: CHARTing a course to bring Environmental Justice to the Coast”). Following the success of CHARTing I, Savannah State did a second round of IP activity, called CHARTing II. The Team Reflection and individual faculty reflections document robust inter-college collaboration among the College of Science & Technology, the College of Business Administration, the College of Liberal Arts and Social Sciences, and the School of Teacher Education.⁵⁷ These collaborations support two efforts that have strong potential to persist: an interdisciplinary Emergency Response Training Program for coastal hazards, and establishment of two marine or environmental science options in the science/math/technology part of the Core Curriculum.⁵⁸
- During their IP project, collaborators from the University of Texas at El Paso, El Paso Community College, and the local Early College High School, tightened ties among their institutions by teaching a coordinated and overlapping set of InTeGrate modules, and running workshops attended by instructors from all three institutions.⁵⁹ The UTEP and EPCC leads (Diane Doser and Josh Villalobos) have leveraged their collaboration into two additional NSF-funded projects: REU Site: UTEP-ROCCS (University of Texas at El Paso—Research Opportunities for Community

⁵⁴ Educating Skillful Visualizers, pre-conference workshop outcomes at: https://serc.carleton.edu/highered/skillful_visualizers/workshop_findin.html. InTeGrate materials used as some examples.

⁵⁵ K-12 Educator Program at Goldschmidt Conference with goal of improving awareness and utilization of geochemistry in K-12 classrooms, using InTeGrate materials and approaches: High school level workshop: https://serc.carleton.edu/integrate/workshops/goldschmidt18_hs/index.html. Workshop for K-8 teachers: https://serc.carleton.edu/integrate/workshops/goldschmidt18_k8/index.html K-8 teachers ITG page

⁵⁶ CSU-Chico IP > Improving Programs: <https://serc.carleton.edu/integrate/programs/implementation/chico/program.html#goal2>

⁵⁷ Savannah State University > Making Change Happen > Faculty Reflections & Stories: <https://serc.carleton.edu/integrate/programs/implementation/savannah/reflections.html>

⁵⁸ Savannah State University IP > Improving Programs: <https://serc.carleton.edu/integrate/programs/implementation/savannah/program.html>

⁵⁹ University of Texas El Paso Program Model: <https://serc.carleton.edu/integrate/programs/implementation/program7/program.html>

College Students) and GP-Impact: Service Learning Activities Targeting the Earth Sciences (SLATES).⁶⁰ Both projects advance the InTeGrate themes of faculty collaboration, broadening participation, active learning, and teaching about the Earth in the context of societal problems.

Webinar program

NAGT currently runs a webinar program that is incorporated into its annual budget. The intent is that the scope of that program will expand to include InTeGrate-relevant content as the InTeGrate-funded webinar series winds down.

During the InTeGrate era, the SERC staff and the broader Geo-Ed community greatly increased its capacity for staging, organizing, and learning from webinars. In 2011, when InTeGrate launched, GeoEd webinars were unusual; by 2018, they had become routine. In the meantime, technical infrastructure was assembled, and staff built up expertise.⁶¹

In their analysis of what makes the GeoEd Community of Practice effective, Kastens & Manduca (2017) emphasized the role of the behind-the-scenes technical and managerial infrastructure that underpins the activities of the community members.⁶² The InTeGrate webinar series is a strong illustration of that phenomenon. At one level, all of the teaching is done peer-to-peer, by faculty members of the community, who contribute their time, experience, and insights. But underlying and enabling that peer-to-peer teaching is:

- Virtual meeting software (Adobe Connect, early in the project; Zoom, more recently);
- The SERCkit content management system;
- A SERCkit web page for each webinar, hosted on the InTeGrate website, articulating the goals and agenda, introducing the presenters, and providing a recording of each webinar as well as links to relevant resources;
- Publicity, to recruit attendees;
- Attendee registration process, also handled through the SERCkit;
- A recruitment process for presenters, identifying topics of interest and plausible presenters;
- Skillful coaching to help faculty presenters plan their webinars, so as to include best practices such as opportunities for attendee active participation, reflection, and ample Q&A;
- A dry-run practice session, with further coaching on technology, organization and how to foster interactivity;
- A skilled facilitator who introduces and frames the workshop, moderates the Q&A, feeds links and supplementary information into the chat stream, and troubleshoots technical problems;
- An evaluation process (staff developed a follow-up survey and implemented it in SERCkit, solicit responses, analyze responses, and use feedback to improve format of future webinars).

This list reveals one other type of underpinning that Kastens & Manduca (2017) did not mention. Although most InTeGrate webinar presenters are experienced instructors, they may have relatively little

⁶⁰ UTEP—ROCCS: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1559716&HistoricalAwards=false
SLATES: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1700772&HistoricalAwards=false

⁶¹ InTeGrate's technical, logistical, and organizational ability to host virtual PD events build on earlier experiments by *On the Cutting Edge*; see NAGT Past Professional Development Events at: https://nagt.org/nagt/profdev/past_workshops.html. Early examples include the Climate & Energy Webinar Series in 2011: <https://serc.carleton.edu/NAGTWorkshops/climatechange/webinar/index.html>, and the Spatial Thinking Journal Club in 2012: <https://serc.carleton.edu/NAGTWorkshops/spatial/journalclub2012/index.html>

⁶² Kastens, K. A., & Manduca, C. A. (2017). Leveraging the power of community of practice to improve teaching and learning about the Earth. *Change: The magazine of higher learning*, 49(5), pp. 14-22.

experience with teaching via webinar and/or with teaching colleagues rather than students. In this context, the support provided by the coach/facilitator is critical. Stepping back for a moment from InTeGrate webinars to the broader universe of CoP's, one might describe this role as “facilitator of community interactions,” combining functions of matchmaking, scheduling, coaching, trouble-shooting, evaluating, and curation of lessons learned. There is no obvious job title for such personnel, and no obvious career path that leads to such a role, at least not in the geoscience education ecosystem—and yet such people will be needed if the community of practice is indeed going to function as a mechanism to carry forward InTeGrate's accomplishments.

Pathway to new collaborations to build on InTeGrate's legacy

Several members of InTeGrate's Leadership Team proposed⁶³ a community workshop to catalyze new collaborations that can carry forward InTeGrate's work in areas of teaching, program design, research, professional and workforce development, and the intersections among these realms. The workshop is structured so as to engage colleagues who participated in various aspects of InTeGrate, as well as new faces and new ideas. ‘Making connections that facilitate forward progress,’ or developing communities of practice, is explicitly mentioned among the workshop goals. The workshop, called Earth Education for Sustainable Societies, is taking place in October, 2019.⁶⁴

Sub-claim 3F: InTeGrate has advanced theoretical understanding of the dynamics that make Communities of Practice effective.

Based on observations of the Geoscience Education Community of Practice, as manifested in InTeGrate and its predecessors, as well as other CoP's inside and outside of education, InTeGrate has developed a conceptual systems dynamics model of the some of the important drivers of effective CoP's. The model is illustrated in Exhibit IV-16 and further explicated in Kastens & Manduca (2017).⁶⁵ This model reproduces three important behaviors of the GeoEd CoP: rapid increase in capacity of the community, mutual reinforcement of individuals and the community, and emergence of feelings of energy and appreciation among the community members.

The *individual learning loop* (Exhibit IV-16) works in all learning situations in which an initial increase in knowledge feeds motivation to learn more, which feeds action to learn more, which results in learning. However, in the case of a CoP, amount learned is also mediated by the capacity of the community. The *reciprocal benefits loop* reflects the observation that individual capacity and community capacity ratchet up together, so that when individuals benefit the group benefits, and vice versa. The existence of this loop is supported by the lightning interviews at the 2016 EER (Exhibit IV-8), which documented that participants were both giving and getting from their Rendezvous interactions. The *affective loop* centers on “warm, collegial feeling of belonging and accomplishment,” which leads to a desire to give back to the community. The existence of this loop is supported by the lightning interviews at the 2017 EER (Exhibit IV-11), in which a large fraction of participants spontaneously described their

⁶³ Gilbert, L., R. Teasdale, and C. Manduca. NSF Proposal: Keep the impact growing: A community workshop to build on the legacy of InTeGrate (confidential document).

⁶⁴ Workshop page for Earth Education for Sustainable Societies:
https://serc.carleton.edu/integrate/workshops/sust_societies/index.html

⁶⁵ Kastens, K. A., & Manduca, C. A. (2017). Leveraging the power of community of practice to improve teaching and learning about the Earth. *Change: The magazine of higher learning*, 49(5), pp. 14-22. See also poster at EER 2018: Weaving New Threads into the Geoscience Education Community of Practice: Insights from Lightning Interviews at EER 2015, 2016 & 2018 at:
https://serc.carleton.edu/earth_rendezvous/2018/program/posters/wednesday/202407.html

Rendezvous experience in terms that indicated warm affect, using words and phrases coded as “community,” “networking,” “energized/excited,” “inspired/motivated,” and/or “collaboration.”

The Geoscience Education Research Community has adopted this model⁶⁶ as they work to develop a new collaborative community whose practice is educational research around teaching and learning about the Earth and environment. Other CoP’s descending from InTeGrate can now use this model to plan for and diagnose their own community dynamics.

Synopsis of Claim 3

InTeGrate activities have contributed to the creation and strengthening of a large, nation-wide group and smaller local or topical groups of “people who share a concern or passion for something they do, and who learn how to do it better as they interact regularly”—in other words, Communities of Practice. The overall shared “concern or passion” is teaching and learning about the Earth in the context of societal problems.

“*Interact regularly*” has been accomplished by a jam-packed calendar of workshops, webinars, and team meetings, both virtual and face-to-face. Convenings were structured so as to maximize the opportunities for constructive, deep interactions among colleagues, with a focus on active doing rather than passive listening. Both long-time geoscience educators and faculty new to teaching and learning about the Earth were entrained into community interactions. The expanding pool of InTeGrate-involved faculty shifted through kaleidoscopically-changing configurations of inter-actors, including Materials Development teams, Implementation Program teams, workshop attendees (both as a group of the whole and as temporary table groups), and standing committees (including the Leadership Team, Assessment Team, and Advisory Board).

“*Learn to do it better*” has been accomplished by a varied suite of active-learning opportunities: formal and informal mentoring, panel discussions, share-a-thons, gallery walks, guided opportunities to try new instructional materials, field trips, and brainstorming sessions. The active learning activities were paired with colleague talks, keynote-style expert talks, posters, and a robust collection of web-based materials. Many convenings presented participants with authentic problems to solve, rather than merely with opportunities to learn and discuss. Successful collaborative problem-solving serves three useful purposes: it leads to lasting learning, forges collegial ties, and solves actual problems.

Although not an essential aspect of the usual CoP definition, *co-creation of products of value to the community* was stressed by Kastens & Manduca (2017) as an important aspect of the geo-ed CoP.⁶⁷ InTeGrate teams co-created many things: instructional materials to support 6 courses and 26 modules; 16 program models for improving Earth teaching at a scale larger than a single course; assessments for geoscience literacy, environmental attitudes, systems thinking, and interdisciplinary problem solving; a methodology for guiding and supporting distributed development of instructional materials by interdisciplinary teams with members from different institutions; and a methodology for nationwide assessment of student outcomes, including collaborative scoring and protection of student privacy.

Involvement in InTeGrate was found to be associated with a sense of *being “part of a community of geoscience educators that shares your goals, philosophy, and values for geoscience education.”* The more intense an educator’s involvement in InTeGrate, the more likely he/she is to report being part of such a community, becoming a better educator through interactions with the community, interacting with the

⁶⁶ Geoscience Education Research Community Planning Workshop: Program: https://serc.carleton.edu/earth_rendezvous/2016/program/morning_workshops/w3/program.html

⁶⁷ Kastens, K. A., & Manduca, C. A. (2017). Leveraging the power of community of practice to improve teaching and learning about the Earth. *Change: The magazine of higher learning*, 49(5), pp. 14-22.

Geo-Ed community, and being influenced by the Geo-Ed community in positive ways. On both surveys and interviews, participants in InTeGrate teams describe strong collaborative links that have been forged through InTeGrate, and affective reactions that Kastens & Manduca (2017) termed “warm collegial feeling of belonging and accomplishment.”⁶⁸

InTeGrate’s leadership believes that the communities of practice forged or strengthened during the InTeGrate era have the potential to keep catalyzing new Geo-Ed reform efforts long after InTeGrate’s NSF grant sunsets. They put in place purposeful *structures and arrangements to support such persistence*. InTeGrate’s largest convening, the Earth Educators’ Rendezvous, is now administered by NAGT, and has achieved financial independence by a combination of fee-charging, sponsorships, exhibitors, and encouraging co-location of project team meetings, workshops, and other working groups. The ITG webinar program and audience are being merged into NAGT’s established webinar program, and the Traveling Workshop program is financially self-sufficient under the NAGT umbrella. The HBCU Working Group has found a new institutional home--as the HBCU Geoscience Working Group--within the National Technical Association. Several of the IP teams are continuing their collaborative efforts with either institutional funding or grant funding.

Both collectively and individually, InTeGrate veterans now have a deeper understanding of what it takes to create and maintain an effective Community of Practice. Some slivers of this understanding are captured in the systems dynamics model published by Kastens and Manduca (2017). Other important facets are embodied in the worldviews and habits of mind of some of the thousands of individuals who experienced an InTeGrate-supported convening, and the scores of individuals who took on leadership roles.

InTeGrate Claims 1 and 2 were about what has been accomplished during the InTeGrate award period. Claim 3 is, at its heart, about the future. Only the passage of time will reveal whether InTeGrate has, in fact, given birth to communities of practice that persist into the future and continue to improve and expand the process of teaching and learning about the Earth.

⁶⁸ Op. cit., p. 19.

<i>Exhibit IV-1: InTeGrate Face-to-Face Workshops</i> (source: https://serc.carleton.edu/integrate/workshops/index.html)			
	<i>Title</i>	<i>Date, Venue</i>	<i>Comments</i>
36	<i>Earth Educators' Rendezvous 2019</i>	July 15-19, 2019, Tennessee State and Vanderbilt U.	First EER to be hosted by a Historically Black College or University.
35	Diversity, Equity, and Inclusion in the Earth and Environmental Sciences: Supporting the success of all students	April 10-12, 2019, Univ. of Illinois at Chicago	Workshop facilitators draw from leadership of UTEP and UIC IP's.
34	Engaging Environmental Justice in Geoscience Courses	Dec. 10, 2018, at AGU in Washington, D.C.	Held in conjunction with the American Geophysical Union annual meeting. Workshop facilitators draw from HBCU Working Group.
33	Engaging Students in Understanding the Earth System as it Intertwines with Key Societal Issues	August 14 & 16, 2018, Boston, MA	Held in conjunction with the 2018 Goldschmidt Conference, an international conference for geochemists. A one-day workshop for K-8 teachers and a one-day workshop for high school teachers. Co-sponsored by NAGT.
32	Connecting Earth Science and Sustainability to Teach the NGSS	August 1-3, 2018, Bainbridge Island, WA	For middle and high school teachers, with focus on NGSS practices. Workshop facilitators draw from the Washington State IP.
31	<i>Earth Educators' Rendezvous 2018</i>	July 16-20, 2018, Univ. of Kansas	Leadership by NAGT.
30	Sustainable Solutions to Societal Issues	Dec 12, 2017, at AGU in New Orleans	Held in conjunction with the American Geophysical Union annual meeting. Dissemination workshop within Geo.
29	Putting Sustainability into Action: New Strategies for Courses and Programs	October 26-28, 2017, Florida A&M Univ.	Builds on HBCU working group experience and expertise.
28	<i>Earth Educators' Rendezvous 2017</i>	July 17-21, 2017, Univ. of New Mexico	Leadership shared by NAGT.
27	Teaching about Earth Online	May 30-June 1, 2017, Penn State Univ.	Builds on Penn State IP experience.
26	Earth in Context: Resources for integrating Earth literacy with societal issues across the curriculum	May 26, 2017 at GSA Cordilleran Section meeting	Dissemination workshop within Geo.
25	Pan-African Approaches to Teaching Geosciences	May 23-25, 2017, Morehouse College	Builds on HBCU working group experience and expertise.
24	Strengthening Geoscience Competency for HBCU Pre-service Teachers	February 2-4, 2017, Tennessee State Univ.	Builds on HBCU working group experience and expertise.

23	Teaching Science in Society: Building Relevance and Interest for Undergraduates by Adding InTeGrate Resources to your Class	August 7, 2016, at the Ecological Society of America Annual meeting, Ft. Lauderdale	Dissemination workshop; outreach outside of Geo.
22	<i>Earth Educators' Rendezvous 2016</i>	July 18-22, 2016, Univ of Wisconsin, Madison	Leadership transferred to NAGT.
21	Teaching Geoscience in Society: Building Relevance and Interest in the Geosciences by Adding InTeGrate Resources to Your Class	Dec. 14, 2015, at AGU Fall Meeting	First workshop in which InTeGrate instructional materials were available for dissemination.
20	Building your Teaching Skills: For Graduate Students and Post-docs	Dec 13, 2015, at AGU Fall Meeting	Led by InTeGrate PI, but not yet using InTeGrate materials.
19	Partnership Workshop: Colorado's Changing Energy Portfolio	Nov. 14-15, 2015, Univ. of Colorado	For Community College Faculty, in partnership with CIRES Education & Outreach.
18	Partnership Workshop: (Re)Designing your Earth-related Course for Improved Student Learning	Oct. 23, 2015, University of Washington-Tacoma	Part of the NAGT Traveling Workshops Program; however, open to faculty from all institutions.
17	<i>Earth Educators' Rendezvous 2015</i>	July 13-17, 2015, Univ. of Colorado	Leadership and financial support shared between InTeGrate and NAGT.
16	Coastal Hazards, Risk & Environmental Justice	May 20-22, 2015, Tulane Univ., New Orleans	Intended for minority-serving institutions and faculty serving populations that are under-represented in geosciences.
15	Partnership Workshop: Student Learning about Critical Earth Issues through the Use of Large Online Digital Data Sets	May 6 – June 24, 2015, Virtual. Six 2-hour sessions.	Collaborative with <i>On the Cutting Edge</i> .
14	Partnership Workshop: Making Good Courses Great with Educational Technology	Jan. 12-16, 2015, Virtual (3-4 hours for each of 5 days over two weeks)	Collaborative with <i>On the Cutting Edge</i> .
13	Partnership Workshop: Undergraduate Research in Earth Science Classes: Engaging Students in the First Two Years	Aug. 10-13, 2014, Montana State Univ.	Collaborative with <i>On the Cutting Edge</i> . In-gathering opportunity for “teaching with authentic, credible geoscience data” rubric guideline, and recruitment/retention of majors.
12	Partnership Workshop: Teaching Geoethics Across the Curriculum	June 10-13, 2014, Chico Hot Springs, Pray, MT	In-gathering opportunity for GeoEthics in the context of sustainability. Collaborative with <i>Teaching GeoEthics across the Curriculum</i> project, and co-sponsored by <i>On the Cutting Edge</i> .
11	Teaching about Risk and Resilience: Sea Level Rise, Flooding, and Earthquakes	May 14-16, 2014, Florida Atlantic University	In-gathering workshop for “teaching about the Earth in the context of societal problems” rubric guideline.

10	Partnership Workshop: Getting the Most your of your Introductory Courses	March 10-12 and 17-18, 2014, Virtual.	Collaborative with <i>On the Cutting Edge</i> .
9	Broadening Access to Earth and Environmental Sciences: Increasing Diversity of Undergraduate Students Learning about the Earth	Feb. 23-25, 2014, Arizona State Univ.	In-gathering workshop for approaches for STEM talent enhancement across all student populations.
8	Geosciences and the 21 st Century Workforce: Considering undergraduate programs in the context of changing employment opportunities	June 26-28, 2013, Penn State Univ.	In-gathering workshop for approaches to STEM talent expansion across school>workforce pipeline.
7	Partnership Workshop: Teaching Oceanography	June 18-20, 2013, City College of San Francisco	Collaborative with <i>On the Cutting Edge</i> .
6	Teaching Environmental Justice: Interdisciplinary Approaches	April 14-16, 2013, Carleton College	In-gathering workshop for STEM Talent expansion into URM communities, and also for teaching the Earth in the context of societal problems.
5	Engineering, Sustainability, and the Geosciences	March 6-8, 2013, Colorado School of Mines	In-gathering workshop on approaches for teaching about the Earth outside of Geo departments.
4	Systems, Society, Sustainability and the Geosciences	July 24-26, 2012, Carleton College	In-gathering workshop for approaches for teaching the Earth in the context of societal problems.
3	Teaching the Methods of Geosciences	June 27-29, 2012, Montana State Univ.	In-gathering workshop for approaches to support rubric guiding principle re nature and methods of geoscience and geoscientific habits of mind.
2	Partnership Workshop: Teaching Environmental Geology	June 2-6, 2012, Montana State University	Collaborative with <i>On the Cutting Edge</i> .
1	Programs that Bring together Geoscience and Sustainability	May 23-23, 2012, Stanford Univ.	This was an in-gathering workshop for ideas that might become Implementation Programs.
AGU: American Geophysical Union; HBCU: Historically Black colleges and universities; GSA: Geological Society of America; NAGT: National Association of Geoscience Teachers.			

Exhibit IV-2: History of Earth Educators' Rendezvous

<i>Year</i>	<i>Locale & website</i>	<i>Approx # EER registrants</i>	<i>Approx # of attendees</i>	<i>% previous EER</i>	<i>% previous SERC</i>	<i>ITG: NAGT cost share</i>
2019	Co-hosted by Tennessee State and Vanderbilt Universities https://serc.carleton.edu/earth_rendezvous/2019/index.html	301	301	42%	48%	0:100
2018	University of Kansas, Lawrence https://serc.carleton.edu/earth_rendezvous/2018/index.html	235	233	49%	53%	0 : 100
2017	University of New Mexico, Albuquerque https://serc.carleton.edu/earth_rendezvous/2017/index.html	360	342	38%	58%	0 : 100
2016	University of Wisconsin, Madison https://serc.carleton.edu/earth_rendezvous/2016/index.html	324	326	31%	57%	0 : 100
2015	University of Colorado, Boulder https://serc.carleton.edu/earth_rendezvous/2015/index.html	315	301	N/A	66%	20 : 80

Notes:

- Data received from Kathryn Sherriff, SERC, October 17, 2018 and updated by Kristin O'Connell 20 November 2019. File EER comparison_participants_year.xlsx.
- Numbers of registrants and attendees approximated from registration data, including registration forms/payments, notes regarding withdrawals, and no-shows inferred based on participants not checking in to the registration table to receive their name tag.
- % previous EER had registered for the EER in one or more previous years.
- % previous SERC had previously attended a non-EER SERC-supported event (includes workshop, webinar, planning meetings, journal club).

Exhibit IV-3: Themes of Traveling Workshop programs. Building Strong Departments & Programs evolved from the pre-InTeGrate era program *Building Strong Departments*; the other themes were developed with InTeGrate support. Uptake of the more environmentally and societally oriented themes started slowly, but picked up in 2018.

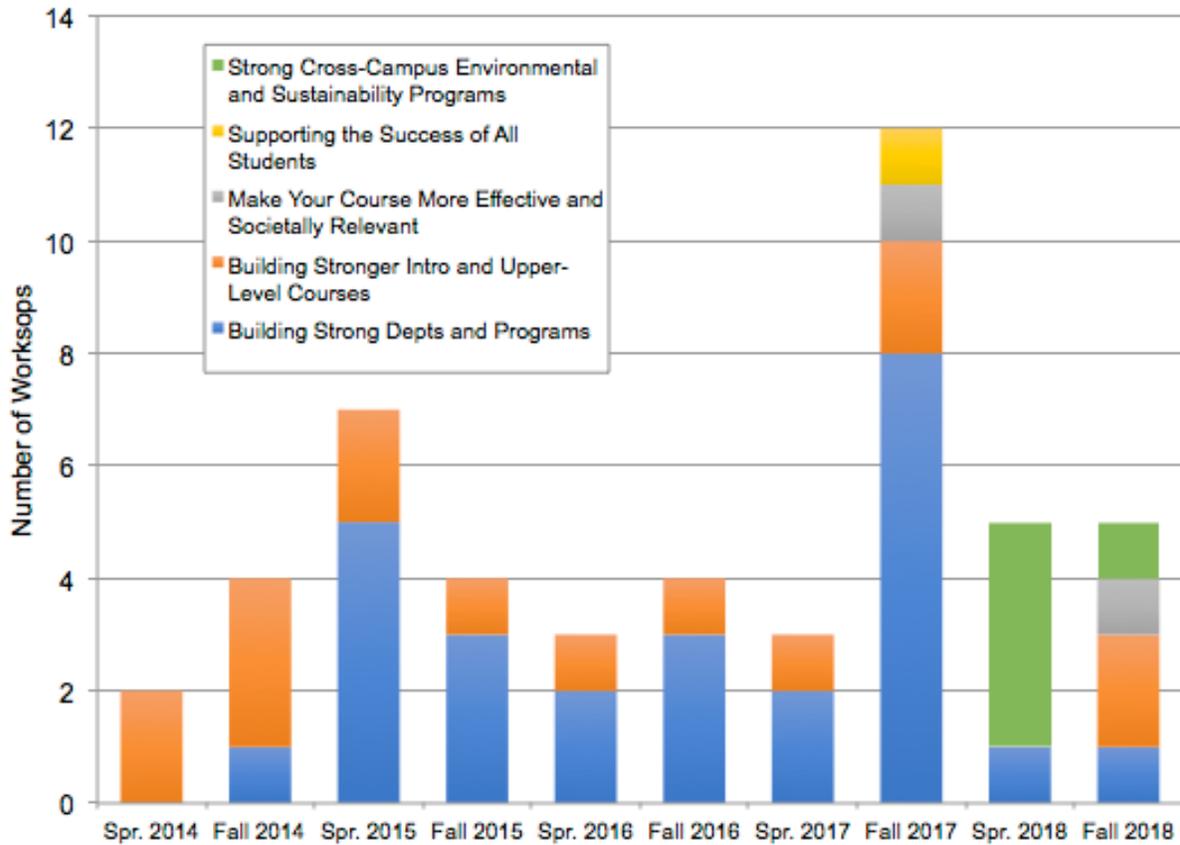


Exhibit IV-4: History of InTeGrate Webinars

	Title	Date	Comments
67	Lessons learned from InTeGrate's Materials Development Program and What Remains Undone	Oct. 1, 2019	Preparation for people attending the Workshop on Earth Education for Sustainable Societies. Co-sponsored by NAGT.
66	Earth Education for a Sustainable Future: Supporting Departments and Programs through InTeGrate	Sept. 17, 2019	Preparation for people attending the Workshop on Earth Education for Sustainable Societies. Co-sponsored by NAGT.
65	Integrating Energy, Earth and Environmental Education	May 6, 2019	Draws on 3 ITG energy-related modules, and bridges between technical aspects of energy and environmental consequences of energy use. Co-sponsored by AESS and NAGT.
64	Teaching Nanoscience in the Earth and Environmental Sciences	Apr. 29, 2019	Introduces work from a sister project: Teaching Nanoscience across the STEM curriculum.
63	Core Competencies for Sustainability Education Programs	Apr. 26, 2019	Presenters from NCSE introduce the organization's process to articulate "core competencies in sustainability degree programs."
62	Helping your Department or Program to Survive and Thrive in the Changing World of Higher Education	Apr. 18, 2019	Includes the context of pressures facing higher education and practical strategies. Co-sponsored by AESS and NAGT.
61	Students as Bridges between Disciplines and Across Campus for Sustainability	Mar. 28, 2019	Program includes both faculty and student presenters. Co-sponsored by AESS and NAGT.
60	Preparing your Students for Environmental Careers: 10 Steps to Improved Eco-Career Prep	Mar. 7, 2019	Presenters include career counselors/advisors and a program director. Co-sponsored by AESS and NAGT.
59	Departmental Climate and GeoEthics	Feb. 7, 2019	Presents suggestions on how to assess your departmental climate and prevent or mitigate threatening situations.
58	Supporting All Students through Active Learning	Dec. 7, 2018	Introduces education research findings that active learning especially benefits students from underrepresented groups, plus pedagogical discussion using ITG examples.
57	Pathways to Performance Expectations using InTeGrate Materials	Nov. 15, 2018	Showcases the mapping between NGSS elements and InTeGrate modules, for pre-service and in-service K-12 teachers and teacher-educators.
56	Sustaining Your Interdisciplinary Environmental and Sustainability Program: Opportunities and Resources	Oct. 31, 2018	Features speakers and resources from SERC, NAGT, AESS, and NCSE.
55	Context Diversity: A New Paradigm for Equity and Inclusion in Higher Education	Oct. 22, 2018	Focuses on how to create an inclusive environment that attracts a diverse population, helps everyone thrive, and values a broad view of success in STEM.
54	Introductory InTeGrate-rich Physical Geology Course	Sept. 28, 2018	Incorporates elements from 3 ITG modules. Presenter is a co-lead of the ITG Research Team.
53	Communicating Science to a Broad Audience: Social Media for You and Your Students	May 31, 2018	Presenters include the informal education specialist from IRIS and the outreach specialist from UNAVCO.

52	Exploring ways to Make the InTeGrate Mineral Resources Module your Own	May 29, 2018	Presentation/discussion led by an instructor who had adapted an ITG module (rather than the more common developer-presenter).
51	Teaching Ocean Sustainability using Active Learning Techniques	May 21, 2018	Based on ITG Ocean Sustainability module.
50	Critical Zone Science: A Transdisciplinary Approach to Environmental Science	May 17, 2018	Based on ITG course: Critical Zone Science.
49	Integrating GPS, SfM, and TLS into Geoscience Field Courses	Apr. 24, 2018	Provides an overview of two GETSI modules.
48	Addressing Landslide Hazards in Introductory Undergraduate Courses	April 18, 2018	Includes a science talk and a linked pedagogy discussion, based on GETSI module: Surface Process Hazards.
47	Educating Skillful Visualizers	Mar. 30, 2018	Features insight emerging from interdisciplinary workshop held in conjunction with Gordon Research Conference on Visualization in Science & Education. Used ITG examples.
46	Addressing Critical Issues in your Community: Examples for Introductory Courses	Feb. 28, 2018	Gives examples of getting out of the classroom and into the community via outreach, advocacy, research in-service to partners, and knowledge co-development. Co-sponsored by AGI.
45	Interdisciplinary Teaching and Sustainability	Feb. 15, 2018	Uses examples from a special issue of JGE on interdisciplinary teaching & sustainability (JGE, v. 65, issue 2, May 2017).
44	Teaching Sustainability in an Interdisciplinary First-Year Seminar	Feb. 9, 2018	Co-led by a geology professor and a sociology professor. Draws from ITG modules: Map your Hazards!; Climate of Change; and Humans' Dependence on Mineral Resources.
43	Designing Activities for Effective Online Teaching	Jan. 22, 2018	Draws from Penn State IP.
42	InTeGrate 101: How to Incorporate InTeGrate Classroom Materials into your Courses	Dec. 8, 2017	Draws from InTeGrate modules: Interactions between Water, Earth's Surface & Human Activity; Systems Thinking; and Major Storms & Community Resilience.
41	Ways to Support All Students	Nov. 13, 2017	Draws from UTEP IP. Focuses on "Ways to Support All Students," based on Jolly et al., 2004, <i>Engagement, Capacity & Continuity</i> .
40	Strengthening K-8 Teacher Preparation	Sept 27, 2017	Connects InTeGrate materials and goals that address Next Generation Science Standards.
39	Sustainable Solutions to Societal Issues: Teaching Earth literacy across the undergraduate curriculum	Sept 21, 2017	Provides general intro to InTeGrate materials and their connection to NAGT/InTeGrate traveling workshop program.
38	Using Model-based Reasoning and Experiential Learning to Understand and Improve Sustainability in a Campus Food System	Sept. 12, 2017	Features links between InTeGrate and EMBERS project (Employing Model-based Reasoning in Socio-Environmental Synthesis: http://embers.cybershare.utep.edu/index.html).
37	Assessing the Impact of InTeGrate Materials in Introductory Environmental Science & Botany Courses	August 31, 2017	Describes a use of InTeGrate materials through the QUBES InTeGrate Faculty Mentoring Network (FMN). QUBES supports education in quantitative biology.

36	Moving Sustainability forward through Community Partnerships, Collaborative Initiatives, and Earth Advocacy	May 8, 2017	Draws on experience of the Wittenburg Univ. and Shippensburg Univ. IP's.
35	Addressing Earthquake Hazards with LiDAR, GPS, and InSAR in Upper-level Undergraduate Courses	April 13, 2017	Draws on modules developed through GETSI (GEodesy Tools for Societal Issues). GETSI adapted InTeGrate's materials development rubric and collaborative process.
34	Integrating Hazards and Societal Impact into Your Course	April 7, 2017	Draws on Map Your Hazards module and includes guest presenter from local emergency management agency.
33	Incorporating Environmental Data-Driven Inquiry and Exploration into your Course	March 30, 2017	Features modules developed by the EDDIE project (Environmental Data-Driven Inquiry and Exploration: serc.carleton.edu/eddie/).
32	Fostering Systems Thinking in your Students	March 22, 2017	Draws on InTeGrate modules: Systems Thinking; A Growing Concern; The Wicked Problem of Global Food Security; and Earth's Thermostat.
31	Adapting InTeGrate Modules to Biology Courses and Online Courses	March 8, 2017	Draws on experience of the Wittenburg Univ. IP and Mercer Univ. IP
30	Sustainability across the Curriculum	March 2, 2017	Draws on experience of Claflin Univ. IP and CSU-Chico IP.
29	Water and Food Sustainability	Feb. 15, 2017	Draws on InTeGrate modules: Water, Agriculture & Sustainability and Food as the Foundation of Healthy Communities, as well as experience of the Univ. of South Dakota IP.
28	Addressing Food Security Issues in Your Course	Feb. 9, 2017	Draws on InTeGrate module: The Wicked Problem of Global Food Security and course: The Future of Food.
27	Teaching about the Critical Zone and the Changing Biosphere	Nov. 30, 2016	Draws on InTeGrate course: Critical Zone Science and module: Changing Biosphere.
26	Teaching the Impact of Human Carbon Emissions on the Atmosphere, Oceans, Climate and Economy	Nov. 17, 2016	Draws on 3 InTeGrate modules: Earth's Thermostat; Ocean Sustainability; and Regulating Carbon Emissions.
25	Addressing Energy Sources and their Impact on the Environment	Oct. 28, 2016	Draws on InTeGrate module: Carbon, Climate, and Energy Resources and InTeGrate course: Renewable Energy & Environmental Sustainability.
24	Developing Students' Data Skills	Oct. 13, 2016	Draws on InTeGrate modules: Climate of Change and Living on the Edge.
23	Addressing Water Resources and Sustainability in Upper-level Undergraduate Courses	Oct. 6, 2016	Draws on modules developed through GETSI (GEodesy Tools for Societal Issues) plus InTeGrate module: Water Sustainability in Cities.
22	The Importance of Diversity and Equity in Supporting the Whole Student	Sep. 22, 2016	Draws on experiences from 3 Implementation Programs: Univ of Texas-El Paso; Univ. of Illinois-Chicago; and Savannah State.
21	Teaching Sustainability and Environmental Justice in the Humanities and Social Sciences	Sep. 7, 2016	Draws on experience with Wittenburg IP, and features InTeGrate modules: Mapping the Environment with Sensory Perception and Environmental Justice and Freshwater Resources (Spanish language adaptation).
20	Teaching about Natural Hazards and Risks	Aug. 31, 2016	Draws on 3 InTeGrate modules: Living on the Edge; Natural Hazards & Risks: Hurricanes; and Coastal Processes, Hazards, and Society.

19	Developing Graduate Students' Teaching Capacity with InTeGrate Materials	Aug. 18, 2016	Draws on experience of the Stanford Univ. IP.
18	Transforming Teacher Preparation to Teach for Sustainability	June 2, 2016	Draws on experience of the Washington State IP, and 3 InTeGrate modules: Soils, Systems & Society; Interactions between Water, Earth's Surface, and Human Activity; and Exploring Geoscience Methods.
17	Making Change Happen at Your Institution: How to Overcome Practical Challenges and Build Momentum	May 27, 2016	Guest presenter: Judith Ramaley of the InTeGrate Advisory Board. Aimed at IP leadership.
16	Working with Diverse Students on Societally-Relevant Geoscience Issues	May 11, 2016	Draws on experiences from 3 Implementation Programs: Univ of Texas-El Paso; U of Illinois-Chicago; and Savannah State.
15	Teaching about Soils as a Critical Resource: Materials and Activities for your Classroom	April 21, 2016	Draws on InTeGrate modules: Soils, Systems & Society and A Growing Concern.
14	Improving Climate Literacy through your Undergraduate Course	April 7, 2016	Draws from InTeGrate module: Climate of Change and Gustavus Adolphus College "Climate across the Curriculum" IP.
13	Using Data to Teach about Societally Important Questions	March 23, 2016	Draws on modules developed by GETSI and InTeGrate module Earth Modeling.
12	Interdisciplinary Teaching: Building Sustainability into your Non-science Class	March 9, 2016	Draws on experience of Penn State IP, and the InTeGrate module CliFi: Climate Science in Literary Texts.
11	Connecting Science to Issues of Justice in your Course	Feb. 25, 2016	Draws on experience of Univ. Texas-El Paso IP and InTeGrate module: Environmental Justice and Freshwater Resources.
10	Getting Ready to Pilot	Jan. 7, 2016	Aimed at InTeGrate Materials Developers.
9	Dealing with Copyright	Dec. 4, 2015	Aimed at InTeGrate Materials Developers; repeated topic for new cohort of authors.
8	Metacognition	Nov. 17, 2015	Aimed at InTeGrate Materials Developers; repeated topic for new cohort of authors. Metacognition is an element of the Materials Development Rubric that developers struggle with.
7	Developing Systems Thinking	Oct. 23, 2015	Aimed at InTeGrate Materials Developers; repeated topic for new cohort of authors. Systems thinking is another element of the rubric that developers (and students) struggle with.
6	Adapting InTeGrate Materials to Best Effect	Oct 13, 2015	Early dissemination webinar, with InTeGrate materials, led by an InTeGrate PI.
5	Using the Materials Development Rubric as a Guide for Designing and Implementing InTeGrate Materials	Oct. 8, 2015	Aimed at InTeGrate Materials Developers; repeated topic for new cohort of authors.
4	Expanding the Impact of Your Program	June 18, 2015	Guest presenter: Dr. Judith Ramaley, member of InTeGrate Advisory Board. Aimed at IP leadership.
3	Introduction to InTeGrate Modules—Hands-on, Data-rich, and Societally-relevant Geoscience Activities	April 10, 2015	Introduces earliest InTeGrate modules: Natural Hazards & Risks: Hurricanes; Map your Hazards; Climate of Change.

2	Scaling-up from Classroom- to Program-level with InTeGrate Materials at 2YC's	March 13, 2015	Earliest effort to spread idea of Implementation Programs; draws on UTEP IP, one of the IP's extant from beginning of project.
1	Hands-on, Data-rich, and Societally relevant Geoscience Activities for 2YC Classrooms—An Introduction to the InTeGrate Modules	Feb. 13, 2015	First dissemination webinar. Starts with introduction to What is InTeGrate. Draws on InTeGrate modules: Climate of Change and Humans' Dependence on Earth's Mineral Resources.
<p>Notes:</p> <ul style="list-style-type: none"> • Source: https://serc.carleton.edu/integrate/workshops/index.html • This table lists open webinars that were publicized and made available to the broader community. In addition, there were closed webinars staged explicitly for ITG Materials Developers on topics including Backward Design, Dealing with Copyright, Rubrics, Metacognition, Systems Thinking, Designing and Aligning Assessments, and Learning Goals and Alignment. Descriptions of many of these Materials Development webinars are at: https://serc.carleton.edu/integrate/workshops/webinars/2015/index.html 			

Exhibit IV-5: Professional development and community-building events organized through the HBCU (Historically Black Colleges & Universities) Working Group

Title	Dates & Venue	Focus/Goal	URL
Workshop: Maximizing Geoscience Opportunities through Interdisciplinary Engagement & Outreach	Sept. 2018, Hampton Univ.	Workshop in association with annual conference of the National Technical Association (devoted to helping underrepresented minorities towards STEM careers).	http://ntawebmaster28.wpengin e.com/?page_id=474
HBCU Working Group at Earth Educators' Rendezvous 2018	July 2018, Univ. of Kansas	Plan for ongoing work of HBCU after the InTeGrate era.	https://serc.carleton.edu/integrate/HBCUplan/hbcu_geosciences_working_group.html (restricted access)
EER 2018 public events	July 2018, Univ of Kansas	<ul style="list-style-type: none"> • Mini-workshop on Pan-African approach to Earth education • Mini-workshop on adoption of geosciences in a way that prioritizes diversity & inclusion • HBCU Working Grp round table 	https://serc.carleton.edu/earth_rendezvous/2018/program/index.html https://serc.carleton.edu/earth_rendezvous/2018/program/theme_recruitretain.html
Workshop: Broadening Participation in Geosciences at HBCU	May 15, 2018, North Carolina A&T State University	Panels on state of Geo at HBCU's, what HBCU's can do to bridge the gap, Geo as an inter-institutional effort among HBCUs.	https://ncatresearchdotorg.files.wordpress.com/2018/05/geosciences-workshop-agenda.pdf
Workshop: Putting Sustainability into Action: New Strategies for Courses and Programs	Oct. 2017, Florida A&M Univ.	Multi-disciplinary teams work to develop culturally-responsive practices for embedding sustainability practices into curriculum.	https://serc.carleton.edu/integrate/workshops/sustainability-action/index.html
Workshop: Maximizing Geosciences Education, Research & Workforce Opportunities through Interdisciplinary Engagement	Sept. 2017, Morgan State Univ.	Day-long workshop at the National Technical Assn. for leaders from academia, industry and government.	http://ntawebmaster28.wpengin e.com/wp-content/uploads/2017/10/NTA-2017-Conference-highlights-report1.3-ed.pdf
HBCU Working Group at Earth Educators' Rendezvous 2017	July, 2017, Univ. of New Mexico	Work on InTeGrate supplement, GeoPATHS proposal, and HBCU research program.	https://serc.carleton.edu/integrate/HBCUplan/rend_2017_agenda.html (restricted access)
EER 2017 public events	July 2017, Univ. of New Mexico	<ul style="list-style-type: none"> • Service learning round table • Pathways to Geoscience graduate programs round table • Food-Energy-Water nexus mini-workshop • Using InTeGrate materials with diverse students 	https://serc.carleton.edu/earth_rendezvous/2017/program/search.html#search_text=HBCU https://serc.carleton.edu/earth_rendezvous/2017/program/theme_recruitretain.html
Workshop: Pan-African Approaches to Teaching Geosciences	May 2017, Morehouse College	Develop opportunities for students to learn geoscience in the context of culturally-relevant questions from Pan-African studies.	https://serc.carleton.edu/integrate/workshops/african-education/index.html

Workshop: Strengthening Geoscience Competency for HBCU Pre-Service Teachers	Feb. 2017, Tennessee State University	Collaborative teams from education and STEM departments collaborate to improve teaching of earth science topics on their campus.	https://serc.carleton.edu/integrate/workshops/hbcu_teacher/index.html
HBCU Working Group at Earth Educators' Rendezvous 2016	July 2016, Univ. of Wisconsin Madison	Solidify core of working group, introduce InTeGrate process and materials. Agree on goals, vision, and plan of action.	https://serc.carleton.edu/integrate/HBCUplan/rendezvous_meet.html

Exhibit IV-6: Number of posts in online Communities of Interest associated with InTeGrate modules and courses, from <https://serc.carleton.edu/integrate/participate/communities.html>, with GETSI modules not included. Although faculty say that they want to have virtual communities, and sign up for such communities, the actual amount of traffic in the community email lists is very small, ranging from zero to eleven posts total per community. (Data collected June 12, 2018).

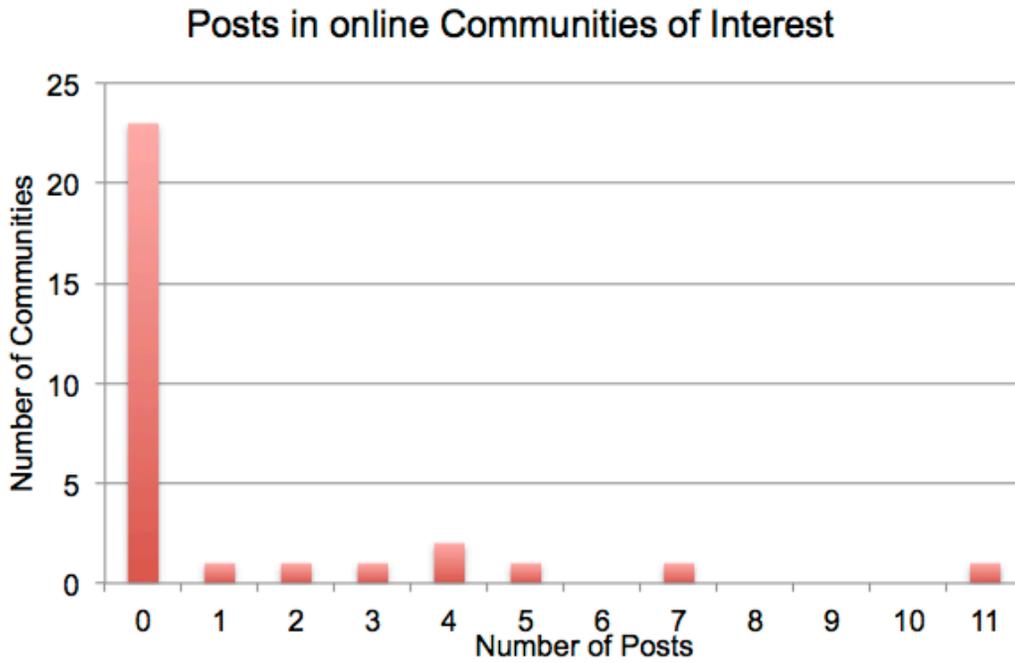


Exhibit IV-7: In lightning interviews, during the 2015 Earth Educator’s Rendezvous, attendees who expressed an interest in continuing to interact with colleagues they had met at the conference were asked about the nature of the ongoing interactions they wished to have. Responses indicate that the Rendezvous is forging new linkages for the exchange of ideas and/or resources around teaching and around education research.

Q#2: "What kind of ongoing interaction...?"

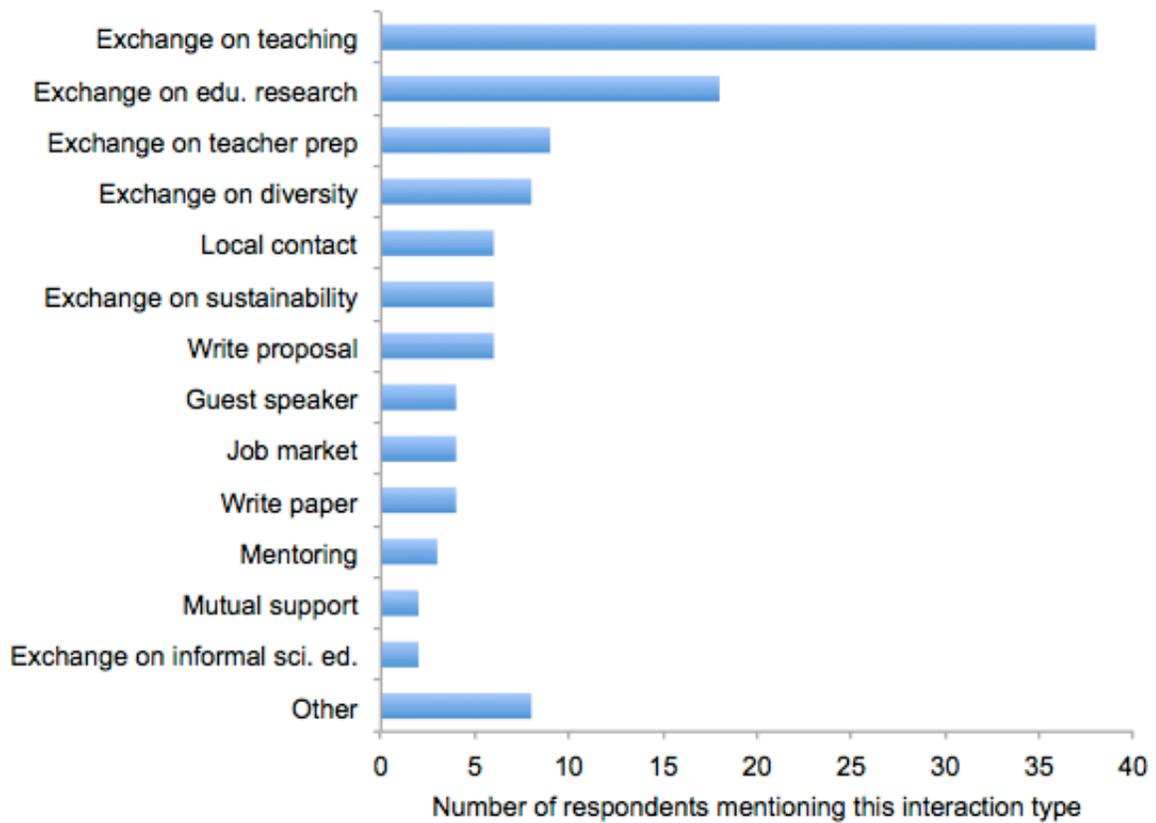


Exhibit IV-8: When 2016 Rendezvous attendees were asked for the ratio or balance they had experienced between “getting” and “giving,” the most common answer was 50:50 (represented in the tallest bar). “Getting” exceeded “giving” for most of the rest of the respondents (right side of graph). Regardless of reported get/give balance, most respondents were satisfied with the balance they had experienced (green shading). These data are consistent with claim that the Rendezvous is functioning as an effective trading zone for reciprocal exchange of resources, ideas, and information.

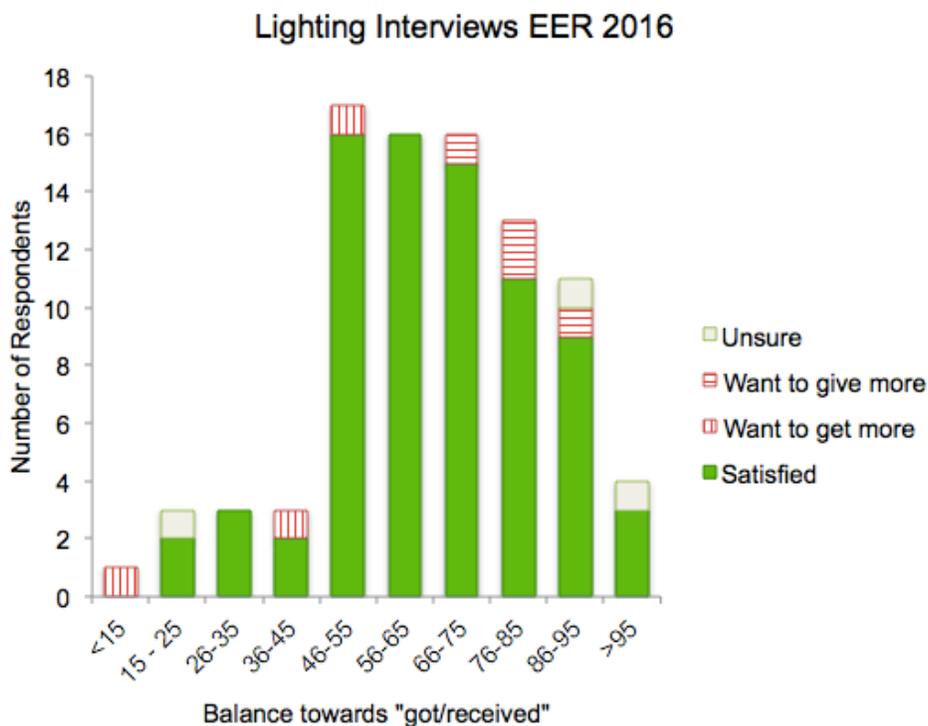


Exhibit IV-9: Although everybody both ‘gave’ and ‘got,’ the reported get:give ratio varied depending on how much previous involvement the respondent had had with the GeoEd community, as either a workshop participant or leader. These data are consistent with a dynamic in which newcomers receive abundant insights, experiences, resources and best practices from the community, and then later provide more back to the community as their expertise grows.

<i>Sub-sample</i>	<i>Number</i>	<i>Mean(SD) “Get” fraction</i>
Newcomers (0 prior workshops)	25	72.5 (17.8)
Medium (1-4 prior workshops)	41	66.2 (16.5)
Veterans (5+ prior workshops)	21	56.2 (23.7)
Non-leaders (led 0 workshops)	71	69.1 (17.8)
Leaders (led or presented at 1 or more prior workshops)	16	50.3 (20.0)

Exhibit IV-10: One item on the survey administered to Implementation Program faculty team members probed the extent to which the IP’s fostered greater collaboration among faculty within and across institutions. Of the 136 IP team members who received the survey, 84 responded for a response rate of 74%. The blue bars below indicate what percentage of respondents selected either “True for me to some extent,” or “True for me to a great extent,” when asked, in reference to five different forms of potential collaboration or engagement, “In what ways has your experience with the InTeGrate Implementation program influenced your interactions related to teaching?” The red bar indicates the percentage of respondents who answered “some extent” or “a great extent” for at least one of A, B, C, D, or E forms of engagement.

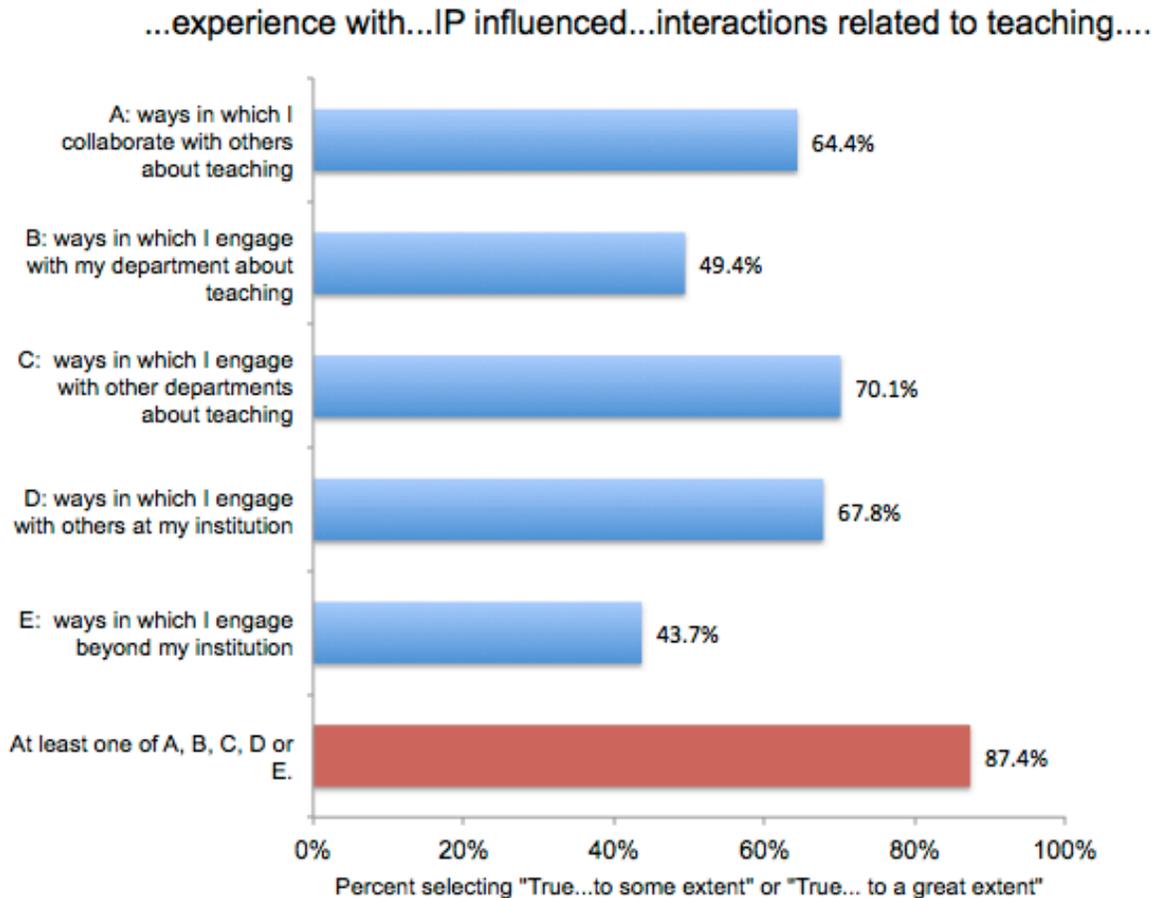


Exhibit IV-11: Attendees at the 2017 Earth Educators’ Rendezvous were asked for 3 words or short phrases that characterized their experience at the Rendezvous. Responses were coded and tallied. Responses that centered on “community,” “networking,” or “collaboration” were taken as evidence that the Rendezvous is viewed as an effective venue for community interactions.

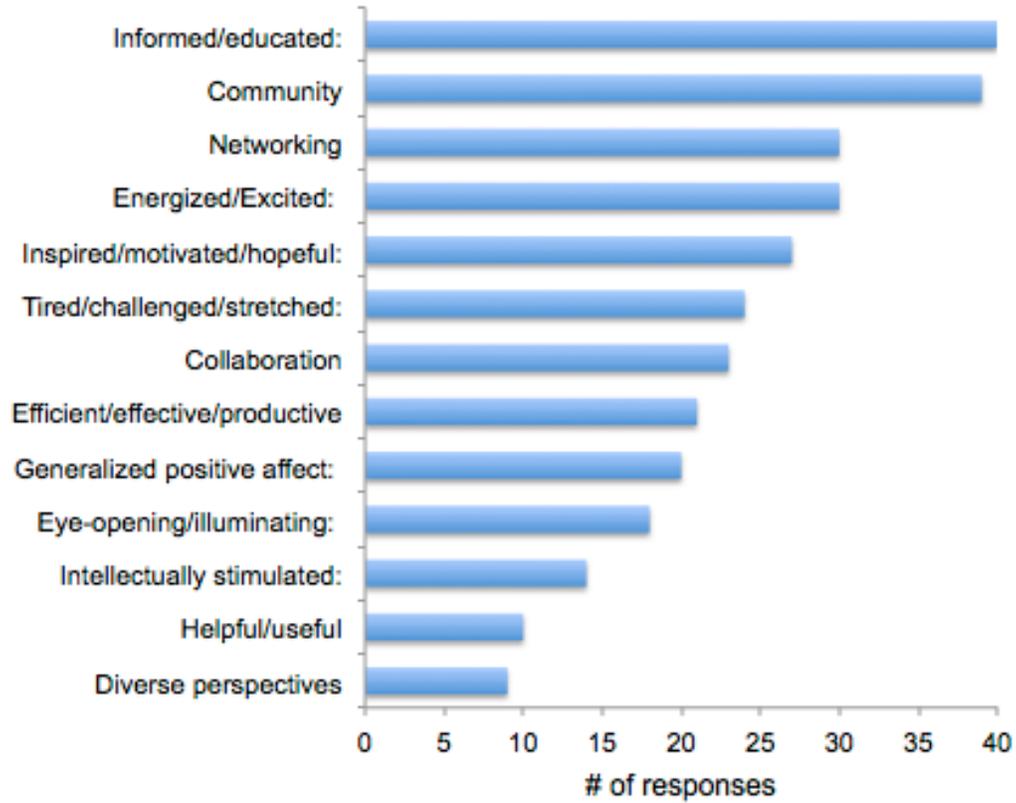


Exhibit IV-12: The 2016 NAGT Survey of Geoscience Faculty Q40 asked: “To what extent do you consider yourself part of a community of geoscience educators that shares your goals, philosophy, and values for geoscience education?” The higher the degree of involvement in InTeGrate (reading left to right across the horizontal axis), the stronger the self-reported sense of affiliation with a community of geoscience educators. Causality is thought to run in both directions, such that stronger community affiliation inclines a person to choose to attend InTeGrate convenings, while participating in InTeGrate convenings helps to build a stronger attachment to the geo-ed community.

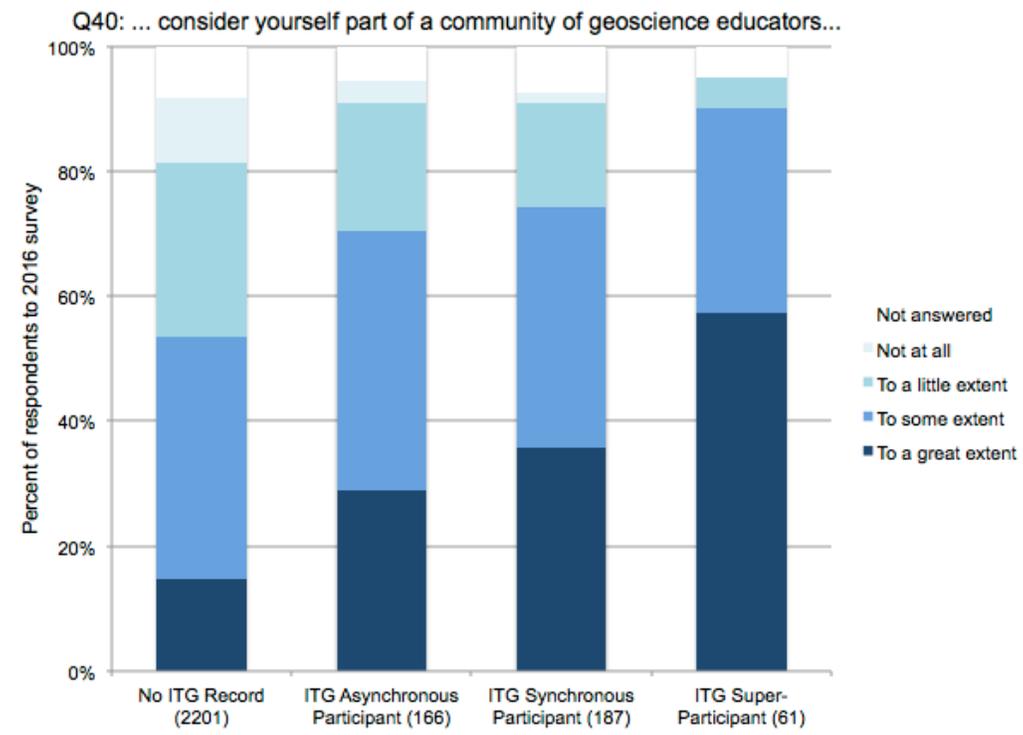


Exhibit IV-13: The 2016 NAGT Survey of Geoscience Faculty Q41 asked: “To what extent do interactions with this community help you become a better educator?” Question 41 shows the same pattern as Q40: the higher the degree of InTeGrate involvement, the more likely the respondent was to say that interactions with [the Geoscience Education] community helped them to become a better educator. Almost nobody selected “not at all.”

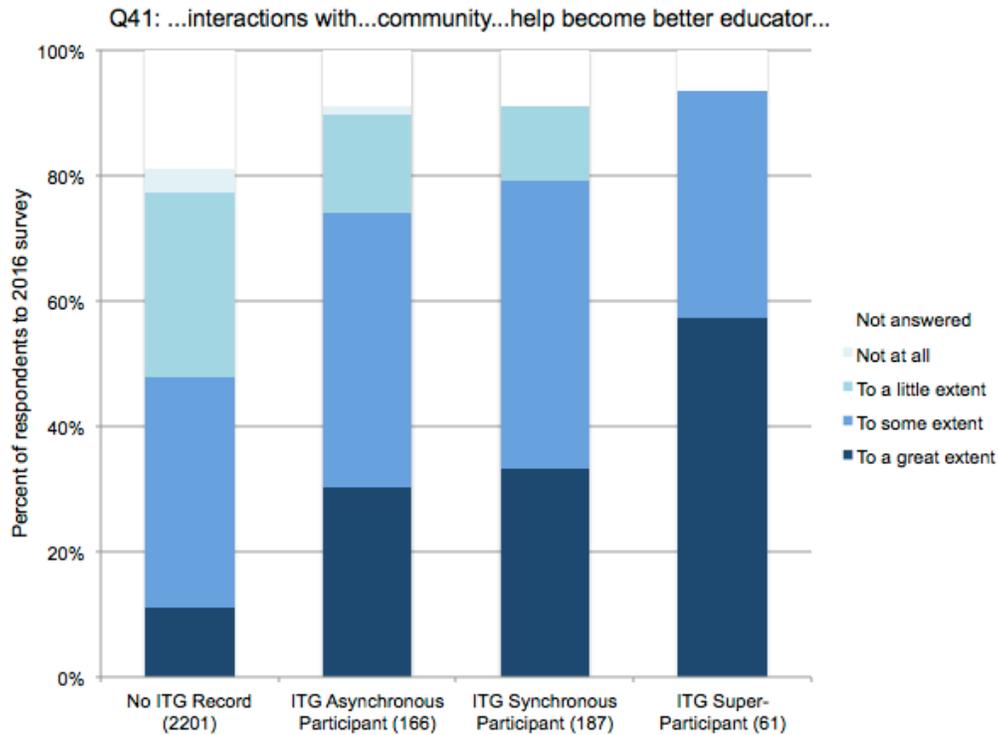


Exhibit IV-14: The 2016 NAGT Survey of Geoscience Faculty Q42 asked: “In which of the following ways do you interact with this community?”

- Seeking people to talk to who have experience relevant to my situation.
- Providing assets or resources to other community members.
- Coordinating or strategizing to achieve a shared goal.
- Discussing developments in geoscience education.
- Finding collaborators for a new project.
- Engaging in deep two-way conversation in support of our educational work.
- Other:”

Question 42 shows the same pattern as the previous two questions: the greater the degree of InTeGrate involvement (reading from lighter to darker color shades), the more likely the respondent was to report that they interact with the [Geoscience Education] community in each of the offered ways. A big step up in degree of reported community interaction comes between “ITG Synchronous Participant” and “ITG SuperParticipant.” All of the offered forms of community interaction were at least moderately popular.

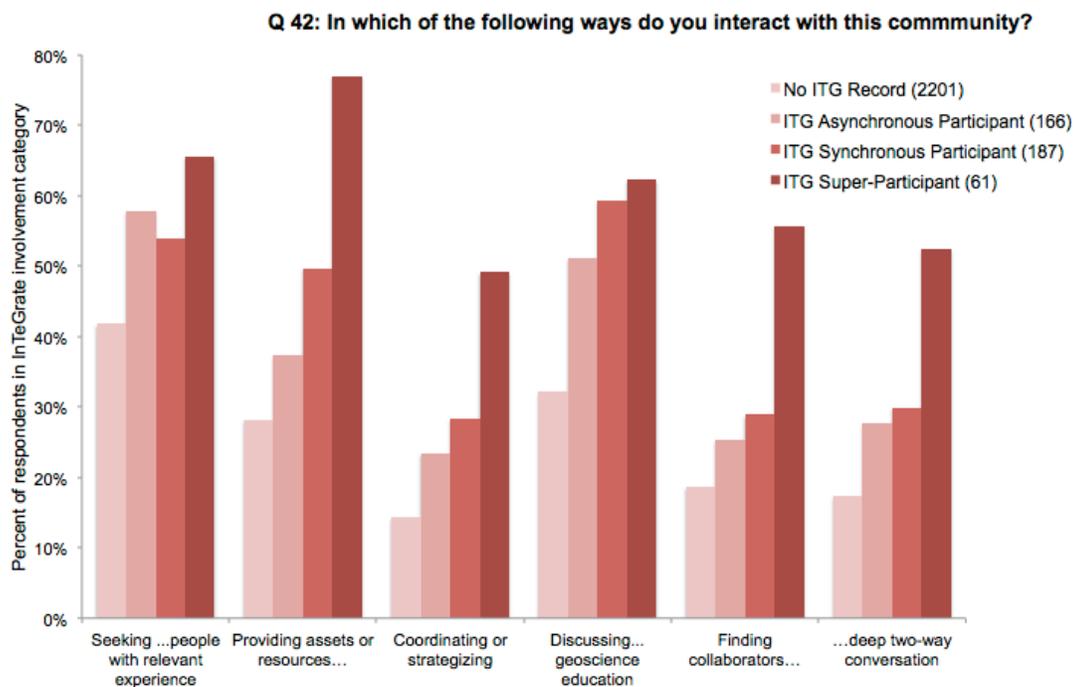


Exhibit IV-15: The 2016 NAGT Survey of Geoscience Faculty Q43 asked: “How have your interactions with this community influenced you?”

- Renewed my enthusiasm
- Built my confidence
- Introduced me to new professional opportunities
- Other”

Question 43 shows a similar pattern to the previous three questions: the greater the degree of InTeGrate involvement (again reading from lighter to darker color shades), the more likely the respondent was to report that they had been influenced by the [Geoscience Education] community in each of the offered ways. Within each group, “renewed my enthusiasm” was the most frequently selected option.

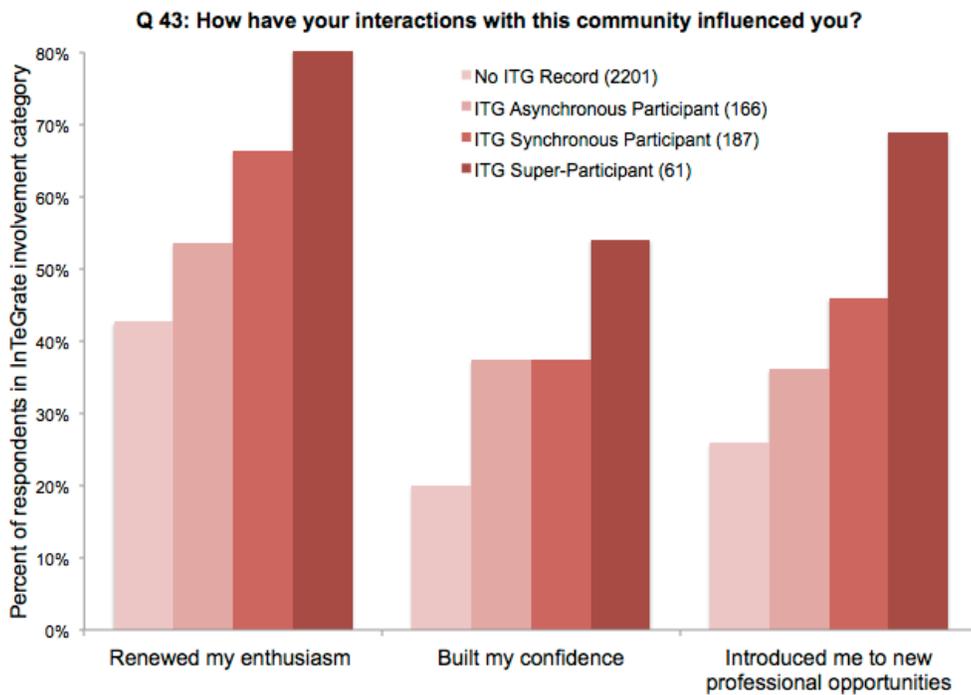
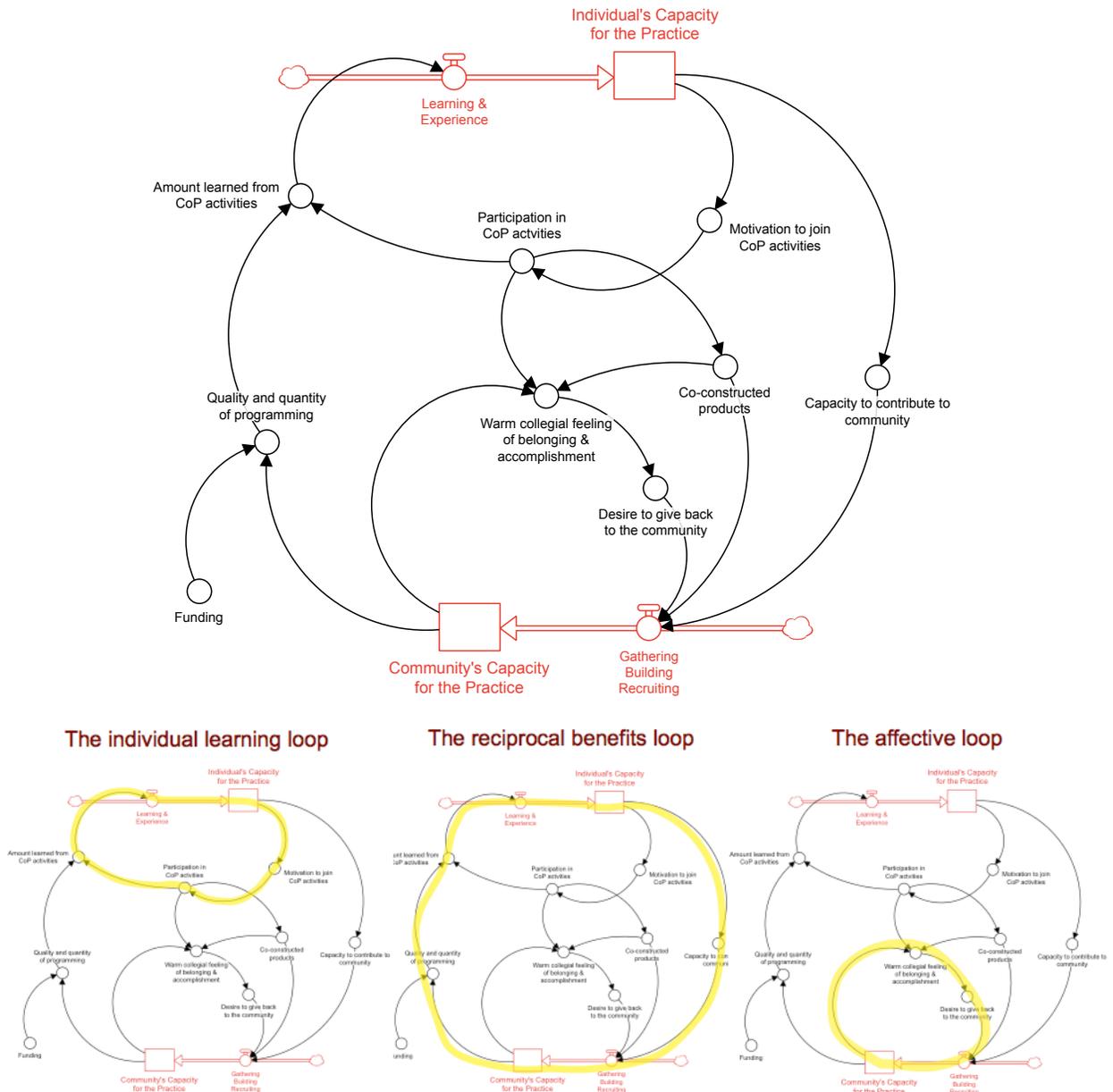


Exhibit IV-16: Based on observations of InTeGrate and its predecessor projects, as well as other well- and poorly-functioning communities, Kastens & Manduca (2017) developed a systems dynamics model in which effective Community of Practices are driven by three intertwined reinforcing feedback loops.



Chapter 5

Reflections on InTeGrate

This brief final chapter tries to provide some insights about why InTeGrate worked as well as it did. What was the secret sauce that made it possible for this project to accomplish so much? What might the designers and leaders of future large education reform projects wish to emulate?

These reflections are the holistic judgment of the author of this report, based on more than 9 years of observation and ongoing engagement with all aspects of InTeGrate effort. These thoughts were informed by a recorded, hour-long round table discussion with the Leadership Team¹ around the question of “Why did InTeGrate work?”, plus email feedback from several Advisory Board members. It’s not possible to gauge or compare the relative levels of impact of these various factors. They are offered as ideas for future project leaders to contemplate, and as hypotheses for future researchers to test.

InTeGrate combined strategies and approaches that would work in any field of education, or indeed in any large, distributed organization, with strategies tailored for education about the Earth.

An example of a strategy that would be applicable to any large organization is to establish multiple nodes with analogous structures, components, mission, information flow, and outputs, e.g. multiple curriculum development teams, multiple IP’s.² Example strategies that would be applicable to education in any discipline are those that tie instruction to important issues that students care about, and that engage students with authentic data. An example of an instructional strategy that is distinctive to--or at least characteristic of--Earth education would be virtual field trips.

The generalizable approaches in InTeGrate’s toolkit tend to be large-scale, and the Earth-specific approaches tended to be smaller scale, with the following exception:

InTeGrate gained energy from the conviction that humanity is facing a profound environmental crisis, and that Earth education can be part of the solution.

InTeGrate demanded a lot from its participants: time, creativity, courage to try something new. Among both the leadership and the rank and file, some found the energy to go the extra mile because of concern about climate change, the sixth extinction, depletion of natural resources, vulnerability to natural hazards, environmental justice, or some looming combination of these and similar threats. These same concerns attracted new people, both faculty and students, to InTeGrate’s offerings.

InTeGrate’s two big reform ideas may have been mutually reinforcing.

InTeGrate’s two big non-negotiable insistences were (1) to teach using student-centered, active-learning pedagogies, and (2) to teach about the Earth in the context of societal problems. Based on faculty interviews, Iverson & Wetzstein (in review) raise the possibility that there is a constructive interaction between these two interventions.³ High-stakes authentic problems form the context and motivation for students to enter into the deep engagement that active-learning pedagogies strive for. Conversely, active-learning pedagogies provide the tool kit that enables students to grapple with high-

¹ Zoom call on February 15, 2019.

² This strategy is articulated in Kastens, K. A., & Manduca, C. A. (2017). Using systems thinking in the design, implementation and evaluation of complex educational interventions, with examples from the InTeGrate project. *Journal of Geoscience Education*, 65(3), pp. 219-230.

³ Iverson, E. R., & Wetzstein, L. (in press). Connecting learning about the earth to societal issues: Downstream effects on faculty teaching. In J. Ostrow (Ed.), *Teaching about Sustainability across Higher Education Coursework, New Directions for Teaching and Learning*, No. 161. San Francisco: Jossey-Bass.

stakes problems in a meaningful way. Thus, A encourages B, and B encourages A, in a virtuous cycle, and the outcome is non-linearly more powerful than either intervention alone.

InTeGrate went where the students are.

Rather than improving education within geoscience departments and waiting for students to come, InTeGrate sent tendrils out into the farthest reaches of higher education. InTeGrate found faculty members who were already teaching some Earth-related content within agriculture, biology, chemistry, economics, education, materials science, physics, and urban studies, and brought them into the InTeGrate community. InTeGrate created curriculum materials and program models to support incorporation of Earth content into business, economics, engineering, Spanish, and literature courses. Collaboration with MSI's, 2YC's, and institutions with no geoscience department, brought quality Earth education to new audiences.

InTeGrate placed great faith in the capacity and motivation of college faculty.

Certain threads of educational reform have advocated for “teacher-proof” curricula: a course of study crafted by professional curriculum designers, and so well structured and so well supported that strong learning gains would happen regardless of the teachers’ actions. InTeGrate took almost the diametrically opposite stance.

For curriculum development, InTeGrate bet that heterogeneous teams of ordinary college faculty, with little to no formal education in curriculum or instruction design, could produce world-class instructional materials, if they had access to appropriate coaching and scaffolding. In large numbers, they rose to the challenge. In retrospect, the 2-3 week module was the appropriate quanta of materials development to ask from faculty members who had full time day jobs doing teaching and/or research.

For curriculum use, InTeGrate also trusted faculty to adapt the provided materials in ways that would be beneficial for the instructor’s unique context and audience. Rather than pushing for “fidelity of implementation,” InTeGrate actively supported adaptation by providing instructors’ stories, variants for some units, links to data sources that would provide geographically optimized data sets for analysis, and so on. It has been suggested, but cannot be proven, that InTeGrate’s high rate of curriculum uptake by non-developer faculty results in part from this adaptability.

InTeGrate combined accountability with support and recognition.

“Trust, but verify.” InTeGrate trusted that faculty and faculty teams could do great work—but set up accountability systems to help keep that great work on track and on schedule. Accountability systems included the checkpoints for materials developers, the quarterly reports of IP leaders, and the independent review of all materials for scientific accuracy. Although the accountability systems set a high bar, InTeGrate also provided extensive mentoring and support towards meeting the expected level of quality and productivity. And then when success was achieved, InTeGrate provided recognition in the form of letters to Deans, press releases, and opportunities to publish.

InTeGrate created leaders.

InTeGrate needed a lot of leaders, at all scales: from national leadership to local IP’s. To get off the ground, InTeGrate mobilized a cadre of existing leaders from across the country who had developed capacity and working relationships from earlier NSF-funded Geo-Ed projects. InTeGrate also created new leaders. A myriad of micro- and mid-level leadership opportunities were built into the structure, such as materials developer, webinar presenter, Rendezvous session leader, workshop co-convenor, and IP leader. Individuals who showed promise in entry-level leadership opportunities were consciously sought out and recruited into more ambitious leadership positions.

InTeGrate recruited world-class advisors, gave them substantial roles, and attended to their advice.

Rather than structuring Advisory Board meetings mostly as opportunities to showcase InTeGrate’s accomplishments, the Board was exposed to InTeGrate’s knottiest problems and entrained in seeking solutions. They rose to the occasion; for example, when InTeGrate struggled to find leverage points for increasing diversity and inclusion, Board member Dr. Judith Ramaley personally provided

mentoring and coaching for two candidate IP teams with strong diversity goals. The Board consistently encouraged the leadership team to think big and think long term. That nudging may have helped the team push back against being overwhelmed by the infinitude of details and decisions.

InTeGrate was designed and implemented using systems thinking.

Kastens & Manduca (2017)⁴ described the process by which InTeGrate's leadership selected which components of the higher education system to target, drove interactions between program components, and set up parallel subsystems with extensive internal information flow and decision-making autonomy. These strategies made it possible for different parts of the system to both benefit from and contribute to one another.

An element not discussed in the earlier paper was the role of people as connecting links who straddled system components, conveying information and insights across boundaries. Ellen Iverson spanned between InTeGrate's Materials Development and Professional Development components. Anne Egger spanned MD, PD, plus the teacher-education community. David Blockstein spanned from InTeGrate outward to the environmental education and sustainability education communities. Felicia Davis spanned from InTeGrate outward to the HBCU community. InTeGrate found suitable bridge persons and then supported their efforts to perform this challenging role.

InTeGrate prioritized improving teaching and learning over researching teaching and learning.

When confronted by a fork in the road where one path offered the potential for more robust educational research findings and the other path offered the potential for greater improvement of teaching and learning about the Earth, InTeGrate prioritized improved teaching and learning. For example, the decision to have to have IP's design and implement their own evaluation plans resulted in an uneven data set that was not ideally suited for education research, as did the decision to proactively encourage faculty to adapt curriculum materials rather than strive for fidelity of implementation. The upside of these decisions is that the faculty had a greater sense of ownership of the materials and evaluation data. Arguably, the materials and evaluation systems were better suited for the particular instructional context, and thus more likely to be continued in use after the end of InTeGrate funding.

InTeGrate consciously planned to leave lasting traces on the landscape of higher education.

InTeGrate leadership adopted the metaphor of a geological event that leaves enduring traces on the Earth even millions of years after the causal impetus has dissipated. Just as a mountain building orogenic event leaves behind metamorphic rocks and distinctive landforms that endure long after the causal compressional forces are gone, so too would InTeGrate leave behind profound changes in Earth education long after NSF grant DUE-1125331 was gone. This intent to leave lasting traces informed the structuring of the Rendezvous, the funding model for the revamped Travelling Workshops, the ramping up of the webinar program, and other large and small decisions.

InTeGrate's idea of leaving lasting traces pertained to people as well as structures. InTeGrate sought to change faculty worldview and priorities, trying to catalyze deeper reflection about what Earth education is for, and how it should therefore be carried out. Such changes have the potential to permeate all facets of the instructor's teaching practice, for life, and to spread from the so-influenced instructor to his or her colleagues, department, and institution. Among students, InTeGrate tried to ratchet up students' motivation to contribute to solving environmental grand challenges, in addition to teaching them to understand how Earth systems work. Changes in worldview, priorities, and motivations are difficult to document, especially on a nationwide scale, but can be felt by participants. In making this choice, InTeGrate tried to focus on what is important, rather than what is measurable.

⁴ *op.cit.*

The success of individual components of InTeGrate depended on the backing of other components, and thus to some extent InTeGrate depended on scale.

InTeGrate's design was such that an output from one component often served as the input to another component. For example, materials developers and IP leaders were able to point faculty users to web pages about pedagogical strategies, specific geoscientific habits of mind, program-building strategies, etc. Those resources existed only because other parts of the larger organization had already created them. The overhead of creating shared structures such as assessment infrastructure, publication template, and materials development rubric was spread across many development efforts. Such a mutually-supportive ecosystem was possible because of InTeGrate's large scale.

InTeGrate tackled many things, all at once.

Scanning down through the project chronology (Exhibit I-4) can give the impression of InTeGrate as a multi-ring circus, and living through it sometimes felt the same way, with way too much going on, all at the same time. Keeping track of the rapidly-growing, far-flung enterprise challenged the project leadership, the PI, the Advisory Board, and the evaluators. But in the deepest vision of what InTeGrate was trying to do, this complexity was a feature rather than a bug. To change the complex system of higher education was seen to require many things to change, *all at once*: the materials with which students were taught, the attitudes of faculty, the programs and departments within which instruction is embedded, and the priorities and value system of the community within which faculty make their decisions.

In addition to faculty, InTeGrate's success built on the capacities of exceptionally talented and hardworking professional staff.

In addition to the nationwide network of faculty participants, InTeGrate benefitted from an exceptionally strong professional support staff at SERC, which provided technical, business, and programmatic underpinnings for InTeGrate's activities. SERC's technology group, under Technology Director Sean Fox, customized faculty-friendly tools for diverse tasks, ranging from surveys and assessments, to work-flow organization, information archiving, event planning, and beyond. The business staff, under Financial and Administrative director Amy Collette, negotiated and oversaw scores of subawards for millions of dollars.⁵ Programmatic support included multiple forms of coaching and organizing, including coaching MD teams on IRB and copyright, bird-dogging materials testers on data submission, facilitating webinars, and planning events. All of these supporting activities benefitted from economies of scale, and from being located at a central, "backbone" organization.⁶

InTeGrate built on decades of prior work, much of it funded by prior NSF projects.

InTeGrate's methods for college faculty professional development through highly interactive, few-day, face-to-face workshops have their roots in *Project Kaleidoscope*, which was founded 30 years ago. Strategies of marrying website and workshop, and the give-a-little/get-a-lot philosophy of peer-supported learning, were perfected during the *On the Cutting Edge* and *Building Strong Geoscience Departments* projects. The Earth Educators' Rendezvous recalls the summer meet-ups held by the Digital Library for Earth System Education (DLESE). InTeGrate's ideas about communities of transformation drew on Kezar and colleagues' synthesis of the PKAL, POGIL, SENCER, and BioQuest projects. InTeGrate's strategy of engaging a large community in development and dissemination of curriculum modules around issues of societal concern built on the work of SENCER. Nationwide online delivery to

⁵ Thirty-two institutional subawards or contracts (e.g. to evaluators, IP's, the HBCU, and Leadership Team members), plus more than 100 small individual awards (e.g. to materials developers and assessment team members). Source: Amy Collette, email, May 31, 2019.

⁶ The idea of a "backbone organization" supporting the collective impact of a distributed network of stakeholders working towards an agreed-upon agenda comes from Kania, J., & Kramer, M. (2011). Collective Impact. *Stanford Social Innovations Review*, Winter, pp. 36-41, online at: http://ssir.org/articles/entry/collective_impact. Functions of a backbone organization identified by Kania & Kramer include project manager, data collector, and facilitator.

increase reach of geoscience curriculum materials had been used by COMET, DataStreme, the Earth System Science Education Alliance (ESSEA), among others.⁷ Without this 30 years of capacity building, the geoscience education community could not have made InTeGrate.

InTeGrate combined repurposed strategies with new elements. The Implementation Program concept was perhaps the InTeGrate component with the scantest evolutionary heritage, the component that most needed to be designed from scratch. Reflecting on how the heritage of these many other projects came together in InTeGrate foregrounds the importance of capturing and sharing the lessons learned from the InTeGrate experience. Much of that knowledge and wisdom is embodied in the people who led and participated in InTeGrate.⁸ This report is an attempt to capture the essence of InTeGrate's approaches and insights for use by future projects.

Not everything worked; InTeGrate learned from failed attempts.

Although report has focused on claims of accomplishments, it is important to recognize that many things that InTeGrate tried did not initially work as hoped. Examples of early failures include the effort to use embedded formative assessments as a project-wide measure of student progress towards learning objectives, the first several versions of the systems thinking essay, and the first several efforts at a diversity program. InTeGrate leadership minimized blame or guilt around these episodes, recognizing that failure is a necessary step towards learning how to do something hard and new. After these non-successes, InTeGrate leadership extracted lessons learned, identified silver linings, and moved on to try again.

The value of time: Five years would not have been enough.

The chronology of Exhibit I-4 shows that by the end of Project Year 5, the project had major accomplishments, including the publication of 16 modules, 16 active IP's, and a vigorous annual Rendezvous. However, had the project terminated at that point, many of the most important lessons learned would not have been nailed down or disseminated. A combination of no-funds-extensions and a supplement extended the project well into 2019, for a total duration of 8 years. During those extra years, the most substantial evaluation and assessment results came out, lessons learned from the IP's were synthesized, the Traveling Workshop program institutionalized the IP's lessons, a book was published about the project, and usage went "viral" and reached beyond early adopter faculty.

It's not over when it's over.

As a funded NSF project, InTeGrate had a beginning, a middle, and end. But as an effort to improve teaching and learning about the Earth, InTeGrate was merely one phase in an ongoing effort that began generations ago, and will continue into the future. InTeGrate's tangible products remain available for use and re-use, including instructional materials, program models, and web-based professional

⁷ *Project Kaleidoscope*: <https://www.aacu.org/pkal>. *On the Cutting Edge* project: <https://serc.carleton.edu/NAGTWorkshops/about.html>. *Building Strong Geoscience Departments*: <https://serc.carleton.edu/NAGTWorkshops/departments/about/index.html>. *DLESE*: Manduca, C., & Mogk, D. W. (2000) *DLESE: A Community Plan: Final Report from the University of Oklahoma to the National Science Foundation Grant 99-06648*. http://d32ogoqmya1dw8.cloudfront.net/files/earthandmind/posts/dlese_community_plan.pdf. *Communities of transformation, synthesizing observations from PKAL, POGIL, SENCER, and BioQuest*: see Kezar, A., & Gehrke, S. (2015). *Communities of Transformation and their Work Scaling STEM Reform*: Pullias Center for Higher Education, Rossier School of Education, University of Southern California, <http://www.uscrossier.org/pullias/wp-content/uploads/2016/01/communities-of-trans.pdf>. *SENCER* (Science Education for New Civic Engagements and Responsibilities): <https://sencer.net>. American Meteorological Society: *DataStreme* Program: <https://www.ametsoc.org/index.cfm/ams/education-careers/education-program/k-12-teachers/datastreme-program/>. UCAR *COMET* program: <http://comet.ucar.edu/index.php>. *ESSEA*: <http://esseacourses.strategies.org>

⁸ ... as would be predicted from InTeGrate's pedagogical stance that one learns by doing, more so than by reading about what others have done.

development materials. The Earth Educators' Rendezvous, Traveling Workshop Program, and webinar program continue as part of NAGT. Students influenced by InTeGrate will carry some of their knowledge and perspectives about the Earth into their adult lives as professionals, parents, citizens, consumers, and decision-makers. Some faculty influenced by InTeGrate will continue to teach in ways that carry forward InTeGrate's guiding principles for the remaining decades of their careers.

Some of the leaders influenced by InTeGrate are moving on to build new ITG-inspired programs.⁹ The curricular materials design model of InTeGrate is the basis for GETSI's ongoing curriculum development effort. Project EDDIE's vision includes a community of instructors using inquiry-based pedagogy and co-developing instructional modules. A GeoPATHS project centered at Savannah State is training a new generation of African American middle school teachers and teacher educators inspired by InTeGrate's vision of teaching about the Earth in the context of community-relevant problems. The Washington State IP team is undertaking an ambitious program to redesign STEM teacher preparation in a collaborative rather than single-institution improvement model.

In October, 2019, a workshop will convene to envision and share ideas for moving forward from the foundation built by the InTeGrate Project.¹⁰ The conferees will find much to build on—but also many remaining challenges. The program models are ripe for replication, and better ways are needed to evaluate innovations at the scale of programs and departments. More instructional materials for upper division majors are needed, as are instructional materials around certain grand challenges such as “providing raw materials for modern society.” The community's ability to assess mastery of higher cognitive level learning goals, such as systems thinking, remains embryonic. InTeGrate tackled only undergraduate education, leaving vast domains of K-12, informal, and graduate/professional education open for ITG-inspired efforts. InTeGrate touched U.S. institutions, but every inhabitant of the planet could benefit from ITG-caliber Earth education. The best ideas of Earth education reformers and researchers are still urgently needed.

⁹ GETSI: <https://serc.carleton.edu/getsi/index.html>. GEOPATHS: Expanding HBCU Pathways for Geoscience Education: https://nsf.gov/awardsearch/showAward?AWD_ID=1802124&HistoricalAwards=false. Project EDDIE: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1821567&HistoricalAwards=false. The Next Generation of STEM Teacher Preparation in Washington State: https://www.nsf.gov/awardsearch/showAward?AWD_ID=1625566&HistoricalAwards=false

¹⁰ Earth Education for Sustainable Societies. Oct 14-17, 2019 workshop: https://serc.carleton.edu/integrate/workshops/sust_societies/index.html