Collaborative Project: EarthCube Education End-User Workshop

Education Development Center, Inc. (EDC), in collaboration with Scripps Institute of Oceanography, propose an end-user workshop to provide input into the design of EarthCube from the perspective of individuals and groups who will be using EarthCube for education. The workshop will bring together educators experienced in teaching with geoscience data, curriculum developers, students, and servers of large geoscience data sets who have education as one of their intended audiences, along with technologists and learning scientists. Sessions will address learning goals and learning performances for the data-savvy college graduate, obstacles to teaching and learning with geoscience data, instructional sequences that foster learning from data, interface design for making data more accessible to student users, and how EarthCube can support students in comparing model output with empirical data. At the end of the project, we will provide a report to the NSF and the EarthCube community addressing the education drivers impacting the design of EarthCube and current challenges in teaching and learning with data that EarthCube could help overcome, with recommendations for the design of EarthCube's cyberinfrastructure and associated social structures.

The *intellectual merit* of the project is that the workshop plan uses the established design principle of backwards design to build the EarthCube requirements for education end users from a vision of what a data-savvy college graduate of the 21st century will need to know, understand, and be able to do. The project draws on the conveners' and workshop participants' deep knowledge of geoscience, geoscience data, geoscience education, learning science, and technology.

The *broader impact* of the project will be college graduates who are ready to go on to graduate school and do world-class research creating and using Earth data, go into the workforce in data-intensive professions such as oil exploration or water resource management, or go into the community prepared to understand data-based lines of reasoning about societal issues such as climate change or hydro-fracking.

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Collaborative Project: EarthCube Education End-User Workshop

Overview:

Education Development Center, Inc. (EDC), in collaboration with Scripps Institute of Oceanography, propose an EarthCube workshop focused on end users who are instructors and learners in educational settings. The goals are to provide input into the design of EarthCube and to improve teaching and learning about the Earth via data and models. The workshop leadership combines expertise in geoscience, geoscience data, and geoscience education. The workshop will be able to build on several previous workshops on use of data in education (Manduca & Mogk, 2002*; http://www.terc.edu/work/967.html; http://serc.carleton.edu/NAGTWorkshops/climatemodels/index.html; http://serc.carleton.edu/NAGTWorkshops/globaldata02/index.html; http://serc.carleton.edu/NAGTWorkshops/tools08/index.html*), extending the vision of these earlier workshops forward into a world in which the cyberinfrastructure for exploring the Earth has been vastly improved beyond today's state of the art. The workshop will be co-sponsored by the National Association of Geoscience Teachers, which provides a ready audience of interested, motivated college faculty for the workshop findings.

We plan a two-day workshop in March 2013 for approximately 40 participants. Attendees will include leaders in teaching geoscience with data and data providers who consider students as one of their important audiences, supported by learning scientists and technologists. The physical workshop will be held at Scripps Institution of Oceanography in La Jolla, California, with a virtual presence on the SERC website (serc.carleton.edu). Workshop sessions will probe (a) learning goals and learning performances for a data-savvy graduate, (b) obstacles and challenges in teaching with data, (c) instructional sequences that will lead to data-savvy graduates, (d) the attributes of EarthCube that would be required to support such instructional sequences, (e) the characteristics of data-access tools that make them useful for students, and (f) how EarthCube could support students' ability to learn from models and data.

As the end goal of an EarthCube-enabled geoscience education, we envision a college graduate who has the skills, knowledge, and disposition to use Earth data to answer questions and solve problems, even in the context of ill-structured problems. By "disposition," we mean that the graduate naturally and spontaneously thinks of data as a necessary or valuable input to a decision-making process. The EarthCube-enabled citizen or professional is the person at the table saying, "Well, what do the data say?" when his or her workgroup or community is confronted with a tough problem or question. Such a graduate will be ready to go on to graduate school and do world-class research creating and using Earth data, go into the workforce in a data-intensive profession such as oil exploration or water resource management, or go into the community prepared to understand data-based lines of reasoning about societal issues such as climate change or hydro-fracking.

Workshop Leaders' Current & Prior NSF support:

Title: Development and Testing of 'Geoscience Data Puzzles': Low-Barrier-to-Entry Data-Using Activities. *Award Number:* GEO-0608057. *Award Period:* 9/1/06–8/31/10. *Amount*: $178,512. *Principal Investigator:* Kim Kastens

This project resulted in the development and testing of a suite of Data Puzzles and associated pedagogical content knowledge (PCK) guides, which were published in book form by NSTA Press (Kastens & Turrin, 2010). Data Puzzles are designed to allow teachers with little prior experience in teaching or learning with geoscience data to transition into teaching with data, and allow students to experience the "a-ha moment" that comes from extracting an insight about Earth processes from data. PCK guides for each puzzle help teachers understand the critical-thinking processes that underlie the data interpretation.

Title: Collaborative Research: Synthesis of Research on Thinking and Learning in the Geosciences. *Award Number:* DRL-0722268. *Award Period:* 1/1/08–12/31/10. *Amount:* $138,196 (Kastens). *Principal Investigators:* Kim Kastens & Cathryn Manduca.

Kastens led a team of five geoscientists, a developmental psychologist, a cognitive psychologist, a cognitive anthropologist, and a philosopher of science to distill what is known and articulate what else is important to know about thinking and learning in geosciences, focusing on spatial thinking, temporal thinking, systems thinking, and learning in the field. Findings were published as a book in the Special Publications series of the Geological Society of America (Kastens & Manduca, 2012).

Title: Collaborative Research: Oceans of Data – What Is Needed to Support Students' Learning with Large Scientific Databases? *Award Number:* DRL-1020002. *Award Period:* 9/1/10–8/31/12. *Amount:* $380,711. *Principal Investigators:* Ruth Krumhansl & Cheryl Peach.

A collaborative project between EDC (PI Ruth Krumhansl) and the Scripps Institution of Oceanography (PI Cheryl Peach), Oceans of Data examined literature and expert opinion from highly diverse fields potentially pertinent to the central project question: "How can the design of electronic interfaces support students' learning with large scientific databases?" The ultimate goal of the project has been to synthesize considerations and guidelines in a knowledge status report to guide the work of interface designers attempting to make scientific cyberinfrastructure databases usable in science classrooms. The Oceans of Data project team reviewed and coded more than 300 articles and books and consulted experts from diverse fields ranging from cognitive science and geoscience education research to computer interface design. The resulting report, *Visualizing Oceans of Data: Designing Educational Interfaces,* presents over 70 specific guidelines for educational interface design, relating to accessing data, geo-referenced data visualizations, graphs, and animations, along with key underpinnings relating to cognitive load theory, visual perception, and schemata. Cross-cutting guidelines also presented in the report highlight the importance of adjusting cognitive load, drawing attention to important features and patterns, and enabling customization.

Workshop Format and Logistics:

The workshop will take place at the Scripps Forum at Scripps Institution of Oceanography, a modern, well-equipped conference facility with good technological support and space for plenary sessions and several concurrent breakout sessions. Participants will be housed within walking distance of the meeting space. Meeting at Scripps allows us to invite local data experts and scientist-educators from multiple geoscience subdisciplines.

Before the workshop, participants will complete a pre-workshop survey. Educator participants will answer basic questions from the EarthCube Workshop question set, such as "What data types do you currently use in teaching?" and "Where do you currently go to get data for use in teaching?" Data-providing participants will be asked a different set of questions, including "What supports do you currently provide for novice users?" and "What do you most want to learn from the educator participants at the workshop?" A compilation of responses will be provided at the workshop to help prioritize the discussions and to help attendees network with kindred souls who share common challenges or goals.

The workshop itself will have some short presentations, but the bulk of the time will be spent on guided discussion (see next section: "Workshop Sessions"). To ensure that the insights emerging from these discussions are captured for future use, we will be using the SERC CMS (Science Education Resource Center; Content Management System) at Carleton College to set up working and recording areas for each plenary and small-group discussion. SERC has perfected this methodology (Manduca et al., 2010) over dozens of workshops (see *http://serc.carleton.edu/NAGTWorkshops/index.html*). Moreover, the geoscience education community is enculturated into using this facility, with hundreds of alumni of *Cutting Edge* and *Starting Point* workshops up to speed on both the technology and the behaviors required to capture workshop discussions onto the SERC website. Working documents will be password protected and available to workshop participants only. A public summary of workshop findings will remain on the SERC website after the workshop.

Workshop Sessions:

In designing the workshop, we are aiming for a mixture of activities that collectively provide both longer term communal benefit and immediate benefit for the individual attendees. Data providers should leave with ideas about how to improve their data access and visualization tools; educators should leave with ideas about how to improve their teaching with data; and the workshop leaders should leave with a clear and concrete vision of how learners of the ideal future would be accessing and manipulating geoscience data and models. Descriptions of seven potential workshop sessions follow.

Readers versed in science education reform will recognize that the first, second, and fourth sessions described below constitute a design process called “backwards design” (Wiggins & McTighe, 2006). In backwards design, one first defines learning goals (what students should know, understand, and be able to do after instruction), then specifies associated learning performances (what observable student products or performances would provide convincing evidence that a learning goal or goals had been mastered), and then designs instruction intended to bring the students to a point where they can produce the desired product or performance. This last step is where one specifies the tools and resources needed (such as EarthCube) in order to implement instruction that achieves the goals.

Learning goals session: What are the attributes of a data-savvy graduate?

In this session, participants will articulate a shared vision of what a data-savvy college graduate of the future will look like. After an education infused with data-using opportunities, what will that graduate know, understand, and be able to do? What habits of mind will the student bring to his or her work with Earth data and models? An illustration of how learning goals can inform EarthCube design is shown in Example 1, next page.)

Learning performances session: How will you recognize mastery when you see it?

The processes that happen inside a student’s mind, like those that happen inside the Earth, cannot be directly observed. Instead, they must be inferred based on indirect lines of reasoning and observable phenomena, sometimes called learning performances. In this session, participants will articulate what students would need to do to demonstrate their ability to use data to answer questions and solve problems. Learning performances will be specified for two levels: the college-entry level and the college-graduation level. A candidate learning performance might be: Given a scientific question, find data suitable for answering the question, create a set of data visualizations that illuminate the situation, formulate a claim in answer to the question, and write a narrative that states the claim and supports the claim with reasoning from data.

Obstacles & problems session: What gets in the way of reaching these learning goals and performances?

In this session, we will capture participants’ experience of what obstacles get in the way of their achieving the ideal learning performances. Obstacles could be of many forms: lack of attention to data-interpretation in pre-college education, user-unfriendly data access and visualization interfaces, difficulty combining multiple data types, and cognitive challenges in connecting representations to referent. Rather than just hosting a gripe session, we will use a balloting system of stickies on whiteboards to capture the workshop’s collective sense of the relative severity of the various obstacles.

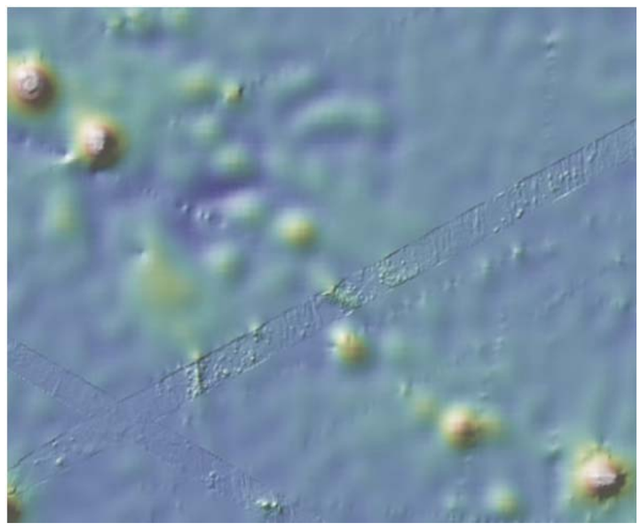
Example 1: How learning goals inform EarthCube design

One learning goal that might come out of the workshop session on learning goals could be: "Students will understand that all data have limitations of accuracy and precision and will have the habit of mind of seeking information about data quality for any data set that they are interpreting." This is a habit of mind that is not common in today's undergraduates.

One of our most common data representations in geosciences is the map, and it is an attribute of maps that they don't have error bars. The geoscience community has a few conventions for indicating data quality on maps (for example, the dashed versus solid line convention for showing less or more well-constrained fault locations), but by and large maps have sparse to non-existent indicators of data quality. An implication of the data quality learning goal is that EarthCube should provide, in an easy to find and easy to interpret format, indications of relative and absolute data quality for data visualizations, including maps.

When geoscience experts were shown this mapview data visualization of seafloor morphology, all but a view spontaneously commented that there were two types of data here: lower resolution data across most of the image, and a swath of higher resolution data crossing the image from SW to NE. Shown the same image, no undergraduate non-science majors commented on data quality.

(from Kastens, Shipley, & Boone, 2012)



Instructional sequences session: What will a lesson of the future look like?

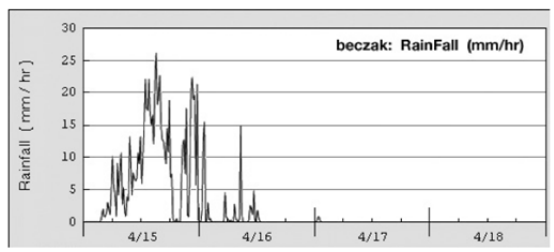
This session seeks to capture, imagine, and share data-using instructional sequences that go beyond the classic cookbook format of "go to this menu; select this item; check this box…." The workshop leaders will kick off the conversation by presenting two instructional sequences that we consider to be promising for building students' ability to make meaning from large, professionally collected data sets. The first is the hybrid activity in which students first collect and interpret a student-collected data set from their local environment, and then interpret their data in a broader context provided by professionally collected data (Example 2). The second instructional sequence is the "hypothesis palette," inspired by Mayer, Mautone and Prothero (2002). Students work with a professional-caliber database, but their explorations are scaffolded by providing a set of alternative working hypotheses. Students choose one hypothesis to defend with reasoning and data, which is an easier task for them than developing an interpretation from scratch.

Additional existing and potential instructional sequences will be gathered from the educators in the group. For each instructional sequence, the workshop will consider what would be the implications for the design of the EarthCube facility, as in Example 2. What would the student need to be able to see, do, obtain, combine, or transform in order to make the desired instructional sequences viable?

Example 2: How instructional sequences inform EarthCube design

One promising instructional sequence is the hybrid activity in which students first collect and interpret a small data set in their local environment, and then download and interpret a larger, professionally collected data set that spans the time and/or place of the student data. The advantage of student-collected data is that students gain an embodied, experiential understanding of the environment from which the data were acquired and a firsthand understanding of the problems and tradeoffs inherent to geoscience field research. The advantage of the professionally collected data is that it lets students address larger research questions, based on more data types or data that spans a larger time and space.

For example, Barnard College students enrolled in Introduction to Environmental Sciences do a day of field work in the Hudson Estuary aboard a small research vessel, measuring salinity, temperature, and other parameters. The student-collected data show a gradual salinity gradient from fresher in the north to saltier in the south, with a “salt front” of steeper gradient. In a hybrid data-using instructional sequence, students would then go on to embed their own data in an extensive professionally collected data set. In the continuously collected data, they could see that salinity at any given station varies over time (below, left), and the position of the salt front shifts up and down river over time. Combining their field experience from one day on the river with the longer time series of archival data, students can interpret the combined temporal/spatial pattern as due to a combination of steady state river input, tides, and rainfall events (below, right).



An implication for EarthCube design is that it should be easy for students to combine data that they have collected themselves with professionally collected data, and to generate data visualizations that show both data sets. One way to do this would be by having “private” areas within the EarthCube data archive into which users could upload data that they had generated. Other users would not be able to access these private data, and the student-collected data would not be commingled with the main EarthCube data sets. But students could use the full suite of EarthCube data analysis and visualization tools on their own data and could view their data in the context of the broader EarthCube data universe: for example, they could add their own data onto the two data visualizations shown above. Through this mechanism, students could become contributors to EarthCube at a young age, as well as EarthCube users.

Data examples from Turrin, M., & Kastens, K. A. (2010)

Interface design session: What should data access look like?

For this session, we will recruit a geoscience data provider to offer his or her data access and visualization tool for critique, aiming for a data tool that was developed for scientists but is sometimes used by students. Krumhansl and Peach will present key findings and recommendations from the Oceans of Data project (Krumhansl, Foster, Busey, Baker, & DeLisi, 2012), in which they synthesized literature and expert opinion on how to make large data sets accessible to inexpert student users. In a hands-on session, workshop participant will try out the offered data access tool, and compare it to the Oceans of Data recommendations and their own vision of an ideal data access tool for students. From this discussion will come specific prioritized recommendations about how the EarthCube user experience should differ from what's available today.

Geoscience models session: How will students compare model output and empirical data?

Although the popular vision of EarthCube is about data access, scientific computational models are an equally important part of the EarthCube plan. In this session, we will try to capture what kinds of computational models are currently in use in geoscience education (e.g., STELLA and EdGCM) and, more importantly, how instructors are currently having students compare and combine models and data. In the epistemology of how geoscientists learn from external—runnable models—a key step is comparing the behavior of the model with the behavior of the Earth as captured in data. Computer scientists are experimenting with computational tools that can support this step (Peter Fox, personal communication, EarthCube Early Career Users Workshop), and EarthCube will incorporate such tools as they become available. This session will dream about how to support students as they learn to make this comparison. A simple form of support could be graphical conventions, such as a certain symbol or icon always indicating what is model output and what is empirical observation from the Earth. A more elaborate support could be a transparent and stepwise tool that methodically tries all variants of model parameters within a specified range, compares them with a specified data universe, and maps the parameter-space of best agreement between model behavior and behavior of the Earth as captured in the data.

Blue-skying the future of EarthCube session: What do you dream about?

Imagine a world with easy, unlimited access to scientific data from any field. Imagine a world where you and your students can easily plot data of interest and display it any way you want. Imagine a world where students can easily model their results and explore their ideas.

What new tools or hardware would you and your students be using? What problems would you want your students to attack? From what fields would you want to have data? What would you be teaching your students?

Invitees:

As with other EarthCube workshops, participants at this workshop will be invited by the workshop organizers to provide specific points of view and voices. The types of voices we wish to have at the table are described below, along with examples of individuals who could provide each perspective. Note that these individuals have not yet been invited or consulted. We provide their names to convey a more concrete sense of what the meeting would feel like, while recognizing that other people with similar expertise may participate instead. Some names appear on more than one list; to keep workshop size manageable, we will favor invitees who can wear more than one hat.

People who have developed curriculum materials using large professionally collected data sets:

- [redacted]

Representatives of organizations that serve large data sets and that value education users amongst their audiences:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

Teachers and professors who have experience teaching with large geoscience data sets:

- *K–12:* [redacted]
- *Community College:* [redacted]
- *B.A./B.S. programs:* [redacted]
- *Informal science education:* [redacted]

Students:

- Two undergraduates (local)
- Two graduate students (local)

Technologists who can provide a reality check on what is possible:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

Specialists in geoscience education /learning science /cognitive science with expertise in how students learn from data:

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

Products:

We will provide to the NSF and the EarthCube community a written report comprising an Executive Summary describing the workshop and its findings, as well as written answers to the EarthCube Workshop questions. Since the needs of our user domain differ somewhat from the science domain workshops, we propose a slightly modified report format, as outlined below. In addition, we would be available to discuss educators' needs with the EarthCube designers, and answer questions about the needs of this end-user group upon request.

(A) Education issues and challenges

i) *Education drivers:* Here we describe the workshop participants' vision of a data-savvy college graduate, who is prepared to use large, professionally collected data sets to answer questions and solve problems, including ill-structured problems and interdisciplinary questions. The description specifies the kinds of learning performances that would document such mastery. We also describe relevant developments in the education landscape over the next 5–15 years, such as the impact of the Next Generation Science Standards, which emphasize interpreting data as a practice of science.

ii) *Current challenges in teaching and learning with data:* Challenges include pedagogical (e.g., need for better instructional sequences beyond the step-by-step cookbook), cognitive (e.g., how humans make inferences from observations is poorly understood), historical (e.g., traditional Earth science textbooks show little of the data upon which the big ideas of the discipline are grounded), as well as technological (e.g., user-hostile user interfaces for some data sets). The focus here will be on challenges towards which EarthCube could contribute solutions; for example, EarthCube could help with the need for better instructional sequences by hosting a reviewed collection of lesson plans and modules that engage students in serious exploration of geoscience data.

(B) EarthCube information/issues/challenges/recommendations

1. *EarthCube technology recommendations:* Here we will summarize recommendations from the education end users that bear directly on EarthCube's cyberinfrastructure design. Examples of what might come out of this discussion would include a capability for student-contributed data (see Example 1) or a mode of use with only modest bandwidth requirements.
2. *EarthCube community recommendations:* Here we will summarize recommendations for the social structures that surround the cyberinfrastructure. An example could be workshops for EarthCube science users on teaching and learning with data held in connection with EarthCube science meetings.

(C) Answers to EarthCube Workshop question template:

1. What challenges do educators have in finding Earth data?
2. Where do educators currently go to get Earth data? What online databases/portals do they use most? What do they like about these data sources? What do they think could be improved?
3. What challenges do students and educators have in learning and teaching with Earth data? Can they easily and efficiently use the data the way they want?
4. What software do educators currently use to interact with data and models? How easy is it to use? What would they like to do that they can't do now?
5. What databases and/or software do educators wish existed that doesn't now exist?

Alignment with NSF expectations for merit and impact

The *intellectual merit* of the project is that the workshop plan uses the established design principal of backwards design to build the EarthCube requirements for education end users from a vision of what a data-savvy college graduate of the 21^{st} century will need to know, understand, and be able to do. The project draws on the conveners' and workshop participants' deep knowledge of geoscience, geoscience data, the geoscience research and education community, learning science, and technology.

The *broader impact* of the project will be college graduates who are ready to go on to graduate school and do world-class research creating and using Earth data, go into the workforce in a data-intensive profession such as oil exploration or water resource management, or go into the community prepared to understand data-based lines of reasoning about societal issues such as climate change or hydro-fracking.

Collaborative Project: EarthCube Education End-User Workshop

Kastens, K. A., & Manduca, C. A. (Eds.). (2012). *Earth & mind II: Synthesis of research on thinking & leaning in the geosciences*. Boulder, CO: Geological Society of America Special Paper 486.

Kastens, K. A., Shipley, T. S., & Boone, A. (2012). *What do geoscience experts and novices look at and what do they see when viewing and interpreting data visualizations?* American Geophysical Union abstract.

Kastens, K. A., & Turrin, M. (2010). *Earth science puzzles: Making meaning from data*. Washington, DC: National Science Teachers Association.

Krumhansl, R., Foster, J., Busey, A., Baker, I., & DeLisi, J. (2012). *Visualizing oceans of data: Designing educational interfaces*. Waltham, MA: Education Development Center, Inc.

Manduca, C., & Mogk, D. W. (2002). *Using data in undergraduate science classrooms.* Carleton College: National Science Digital Library.

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), 1095–1096.

Mayer, R. E., Mautone, P., & Prothero, W. (2002). Pictorial aids for learning by doing in a multimedia geology simulation game. *Journal of Educational Psychology, 94*(1), 171–185.

Turrin, M., & Kastens, K. A. (2010). Is the Hudson River too salty to drink? In K. A. Kastens & M. Turrin (Eds.), *Earth science puzzles: Making meaning from data* (pp. 186). Washington, DC: National Science Teachers Association.

Wiggins, G., & McTighe, J. (2006). *Understanding by design (expanded 2nd edition)*. Columbus, OH: Merrill Prentice Hall.

Biographical Sketch

KIM ANNE KASTENS

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kkastens@edc.org; (617) 618-2506

Professional Preparation:

Yale University	Geology and Geophysics:	B.A.	1975
Scripps Institution of Oceanography	Oceanography	Ph.D.	1981

Appointments:

2012–	Principal Scientist/Distinguished Scholar, Learning & Teaching Division, EDC.
1992–2012:	Adjunct Professor, Department of Earth & Environmental (formerly "Geological") Sciences, Columbia University (1992-1993: Adjunct Associate Professor; 1993-2012: Adjunct Full Professor).
1981–	Scientist, Lamont-Doherty Earth (formerly "Geological") Observatory of Columbia University (1981-1988: Associate Research Scientist; 1988-1991: Research Scientist; 1991-1999: Senior Research Scientist; 1999-2009: Doherty Senior Research Scientist; 2009-2012: Lamont Research Professor; 2012- Special Research Scientist).
1987 (fall):	Visiting Reader, Department of Earth Sciences, Monash Univ., Australia.
1986–1987:	Visiting Lecturer, Department of Geology and Geophysics, Yale Univ.
1976–1981:	Research and Teaching Assistant, Scripps Institution of Oceanography, University of California at San Diego.
1975–1976:	Geological Technician, Marine Science Research Center, SUNY Stony Brook.

Selected Publications: Most closely related

Kastens, K. A. & Turrin, M. (2010). *Earth Science Puzzles: Making Meaning from Data:* Washington, D.C., National Science Teachers Association, p. 186.

Kastens, K. A., Kaplan, D., & Christie-Blick, K. (2001). Development and evaluation of *Where are We?* map-skills software and curriculum. *Journal of Geoscience Education, 49*, 249-266.

Hays, J. D., Pfirman, S., Blumenthal, M., Kastens, K., & Menke, W. (2000). Earth Science Instruction with Digital Data. *Computers and the Geosciences, 26*, 657-668.

Ishikawa, T., Barnston, A., Kastens, K. A., & Louchouarn, P. (2011). Understanding, evaluation, and use of climate forecast data by environmental policy students. In A. D. Feig & A. Stokes (Eds.), *Qualitative Inquiry in Geoscience Education Research: The Geological Society of America Special Paper 474* (pp. 153-170). Boulder, CO: Geological Society of America.

Swenson, S., & Kastens, K. A. (2011). Student Interpretation of a Global Elevation Map: What it is, How it was Made, and What it is Useful for. In A. Feig & A. Stokes (Eds.), *Qualitative Inquiry in Geoscience Education Research* (pp. 189-211): Geological Society of America Special Paper 474.

Other significant publications

Kastens, K. A., & L. S. Liben. (2010). Children's strategies and difficulties while using a map to record locations in an outdoor environment, *International Research in Geographical and Environmental Education*, v. 19, no. 4, p. 315-340.

Kastens, K. A., & A. Rivet. (2008). Multiple modes of inquiry in Earth Science. *The Science Teacher,* January issue, 26-31.

Kastens, K. A., & L. S. Liben. (2007). Eliciting self-explanations improves children's performance on a field-based map skills task. *Cognition and Instruction*. v. 25, pp. 45-74.

Kastens, K. A., Manduca, C. A., Cervato, C., Frodeman, R., Goodwin, C., Liben, L. S., Mogk, D. W., Spangler, T. C., Stillings, N. A., & Titus, S. (2009). How geoscientists think and learn*: EOS, Transactions of the American Geophysical Union,* v. 90(31), p. 265-266.

Kastens, K. A., & Ishikawa, T. (2006). Spatial Thinking in the Geosciences and Cognitive Sciences. In C. Manduca & D. Mogk (Eds.), *Earth and Mind: How Geoscientists Think and Learn about the Complex Earth* (pp. 53-76): Geological Society of America Special Paper 413.

Synergistic Activities:

2000-2002:	Advisory Committee for the Geosciences Directorate, National Science Foundation (Vice-Chair of Committee and Chair, Education and Diversity Subcommittee)
2001-2004:	National Research Council study on "Learning to Thinking Spatially"
2010:	NSF REESE meeting, panel on "Interdisciplinary Research" (http://serc.carleton.edu/earthandmind/posts/interdisciplina.html)
2010-present:	National Research Council, Board on Science Education, study on "Discipline-based Education Research"
2007-present:	Leader: Synthesis of Research on Thinking & Learning in the Geosciences (http://serc.carleton.edu/research_on_learning/synthesis/index.html)

Collaborators and other Affiliations:

(i) Recent Collaborators:

Cinzia Cervato (Iowa State), Robert Frodeman (U of North Texas), Charles Goodwin (UCLA), Marguerite Holloway (Columbia Graduate School of Journalism), Lynn Liben (Penn State), Cathryn Manduca (Carleton), David Mogk (Montana State), Michael Passow (Dwight Englewood H.S.), Ann Rivet (Teachers College), Thomas Shipley (Temple U.), Timothy Spangler (UCAR), Neil Stillings (Hampshire), Margie Turrin (L-DEO), Sandra Swenson (Teachers College), Sarah Titus (Carleton)

(ii) Advisors:

Robert Gordon (Yale University), F. N. Spiess (U California San Diego), W.B. F. Ryan (L-DEO)

(iii) Graduate Students & Postdoctoral Scholars:

Earth & Environmental Science Journalism Graduates: Krista McKenzie, Dina Capiello, Christina Reed, Hannah Fairfield, Naomi Lubeck, Sara Pratt, James Bronzan, Sarah Graham, Adam Rankin, Francesco Fiondella, Akiko Matsuda, Victoria Kauffman, Ken Kostel, John Romano, Laura Wright, Ke Xu, Kristen Fountain, David Epstein, Alisa Opar, Samir Patel, Mohana Kumar, Curtis Brainard, Andrea Gawrylewski, Jeneen Interlandi, Jeffrey DelViscio, Amy Schoenfeld, Joe Spring. Jacoba Charles, Rebecca Gentry, Justin Nobel, Janet Fang, Jessica Leber, Emily Muhlhausen, Katherine Bagley, Rebecca Fried, Adi Narayan, Diya Chacko, Veronica Phillips, Alejandra Borunda.

Post-docs: Kenneth Hurst, Lewis Gilbert, Toru Ishikawa.

RUTH A. KRUMHANSL
Education Development Center, Inc.
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PROFESSIONAL PREPARATION

Bucknell University, Lewisburg, Pennsylvania, B.A. Geology, 1977

Antioch New England Graduate School, M.S. Environmental Studies; Teaching Certification, 1998

Additional coursework at Cornell University, University of Houston, and Rice University in paleoecology, carbonate geology, geomorphology, paleontology, photomicrography, and physics.

APPOINTMENTS

Research Scientist, 2005–present
Education Development Center, Inc., Newton, Massachusetts

Ocean Tracks: Investigating Marine Migrations in a Changing Ocean, Collaborative Project with Stanford University – Principal Investigator of NSF-funded phase 1 project which is developing a unique model of how to enable high school students to use authentic scientific data via an interactive Web-interface. An interactive website provides access to near-real-time and archival data from electronically tagged marine animals, drifting buoys, and Earth-orbiting satellites collected through the Global Tagging of Pelagic Predators (GTOPP), NOAA's Adopt-a-Drifter (ADP), and MY NASA DATA programs. Powerful Web-based visualization and analysis tools—derived from state-of-the-art knowledge about how to support student inquiry with data—allow students to learn and apply core concepts in ecology, biology, environmental science, earth science, oceanography, and climate science.

- *Oceans of Data, Collaborative Project with Scripps Institution of Oceanography*—Principal investigator of NSF-funded exploratory project that informs efforts to bridge scientific cyberinfrastructures to the classroom. Project conducted a multidisciplinary review of studies and expert opinion, with a goal of bringing learning research to bear on the development of electronic interfaces and tools for use by students accessing large scientific databases. Resulting knowledge status report *Visualizing Oceans of Data: Designing Education Interfaces* presents over 70 specific interface design guidelines as well as cross-cutting guidelines and key underpinnings in cognitive science. The report is being disseminated to inform the development of large scientific cyberinfrastructure projects, and to spur additional needed research.
- *Foundation Science: Earth Science*—Lead author of full-year Earth Science course for high school. The curriculum, which was funded by the National Science Foundation, stresses rigorous, inquiry-oriented learning in contexts that are relevant to students. The course explores interactions between the atmosphere, hydrosphere, and geosphere. Students investigate topics such as climate change in depth, and study plate tectonics by analyzing data regarding volcanic and earthquake activity in the western U.S.
- *Exploring the Frontiers of Science with Online Telescopes, Harvard Smithsonian Center for Astrophysics*—Senior research for the Other Worlds/ Other Earths project, which engages high school and middle school students in the use of online telescopes to search for earth-like planets orbiting other stars. Students gather and analyze their own data and publish their findings to a larger community of student and scientific observers. After detecting an actual world, students use interactive animations to model and interpret light curves that might one day be received from an earth-like planet.
- *Data-enhanced Investigations for Climate Change Education (DICCE), SRI International*—Working with SRI International and NASA in the development and piloting of interactive websites for high school classroom climate-change investigations. The websites will allow high school teachers to assemble customized data sets about local climate change from NASA remotely-sensed Earth observation mission

data archived in NASA's Goddard Interactive Online Visualization and Analysis Infrastructure (Giovanni).

- *Electronic Teacher Guide*—Contributed to the development of new content for a prototype of an electronic teacher guide (eTG). The eTG will be an interactive teacher guide that uses the features of new media to support the needs of a range of teachers, customizing the content and providing different interfaces and layers for teacher resources and pedagogical supports..
- *Inquiry Science Instruction Observation Protocol (ISIOP)*—Participated in the development and rigorous testing of an observation protocol that assists evaluators in determining the nature of and extent to which elements of inquiry science instruction are present in precollege classroom teaching. Involved coding teacher verbal practices in dozens of videotaped high school and middle school science classes.
- *DODEA Science Curriculum Guides*—Led the high school team in the development of curriculum guides and sequenced science standards for a total of nine precollege science courses taught worldwide by Department of Defense schools. The work eventually went out to about 84,000 students, in 192 schools, distributed between 12 foreign countries, seven states, and two protectorates. Authored standards and guide for high school Earth and Space Science.

Science Teacher and Science Department Coordinator, 1999–2005
Souhegan High School, Amherst, New Hampshire

Taught an integrated 9th grade course that focused on Earth systems science and physics. The curriculum, which incorporated activities such as geologic mapping, biodiversity monitoring, the evaluation of climate-change evidence, and rocket-building , emphasized deriving knowledge through active student inquiry. Also taught Summer Geology Institute, in which students performed surficial geologic mapping using GIS in partnership with geologists of the U.S. and New Hampshire Geological Surveys.

Chief Scientist/Senior Project Manager, 1985–1998
Environmental Science and Engineering, Inc., New Hampshire
ENSR Consulting and Engineering, Massachusetts

Directed soil and groundwater investigation and clean up work at hazardous waste sites located across the U.S. Coordinated teams of specialists in a variety of scientific and engineering disciplines, including geology, biology, hydrogeology, chemistry, toxicology, ecology, soil science, and civil and environmental engineering. Involved extensive data collection and the use of geovisualizations and models to analyze the extent of contamination and predict contaminant transport.

Petroleum Exploration Geologist, 1979–1984
Husky Oil Company and Transwestern Petroleum, Colorado; Phillips Petroleum Company, Texas

Conducted petroleum exploration studies in Louisiana, Utah, Kansas, and Oklahoma. Scientific work involved analyses of complex data describing rock and fluid properties and three-dimensional subsurface mapping to locate potential oil and gas reserves.

SELECTED PUBLICATIONS AND PRESENTATIONS

EDC Earth Science A full-year high school earth science course. Hard copy to be published in 2013 by Lab Aids.

Gould, R. R., Sunbury, S., & Krumhansl, R. (2012, May). Using online telescopes to explore exoplanets from the physics classroom. *American Journal of Physics, 80*(5), 445–451.

Miller, J.S., & Krumhansl, R. (2009). Learning from innovative instructional materials and making them your own. *Reforming Secondary Science Education.* NSTA Press.

Krumhansl, R., & Wunsch, D.R. (2003). *Surficial geologic mapping as a discovery-based teaching tool for high school students*. Poster session presented at the annual national meeting of the Geological Society of America, Seattle, WA.

Cheryl L. Peach

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EDUCATION

Geological Sciences -Columbia University, New York, NY *The Geochemistry of Platinum Group Elements in Mafic and Ultramafic Rocks*	Ph.D.	1993
Oceanography -College of Ocean and Fisheries Sciences University of Washington, Seattle, WA	M.S.	1987
Environmental Sciences – University of Virginia, Charlottesville, VA	B.A.	1982

EXPERIENCE

2001-present	Director, Scripps Educational Alliances, Scripps Institution of Oceanography, UCSD; Lecturer, University of California, San Diego; Program Scientist: Birch Aquarium at Scripps
2001-present	Adjunct Faculty Member: Sea Education Association, Woods Hole, MA
2000-2001	Interim Dean: Sea Education Association, Woods Hole, MA.
1994-2000	Oceanography Faculty: Sea Education Association, Woods Hole, MA.
1997	Interim Dean: Sea Education Association, Woods Hole, MA
1994	Lecturer in Oceanography: Fairleigh-Dickinson University, Teaneck, NJ.
1992-1994	Assistant Scientist: Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY.
1987-1992	Graduate Research and Teaching Assistant: Lamont-Doherty Geological Observatory, Palisades, NY; Columbia University Faculty Fellow
1990	Instructor: St. Thomas Aquinas College, Orangeburg, NY.
1989	Teaching Assistant, Department of Earth and Planetary Sciences, American Museum of Natural History, New York, NY.
1984-1988	Research Assistant: Los Alamos National Laboratory, Los Alamos, NM. (Summers)
1984-1987	Graduate Research and Teaching Assistant: College of Ocean and Fisheries Sciences, University of Washington, WA
1981	Research Assistant: U.S. Army Corps of Engineers Coastal Engineering Research Facility, Duck, NC

Committees/Advisory Boards:

Chair, Centers for Ocean Sciences Education Excellence (COSEE) Community Meeting Steering Committee (2010-2011)

Chair, National COSEE Council (5/2011-5/2012); National COSEE Council Executive Committee (5/2010-present)

NSF Ocean Observatories Initiative, Education and Public Engagement Team (2007-present)

Scripps External Relations Committee (SERC), (2006 – present).

Advisory Committee University of New Hampshire's NSF GEOTeach Program, Transfomring Earth Systems Science Education, (2005-2010).

Advisory Committee to the Geosciences Directorate, National Science Foundation, (2003-2005).

Chair, Diversity and Education Sub-committee, Advisory Committee to the Geoscience Directorate, NSF, 2003-2005.

Chair, Geoscience Education Working Group II, Geoscience Directorate, NSF, 2004.

Chair, Committee of Visitors, Diversity and Education Programs, Geoscience Directorate, NSF, 2003.

AGU Excellence in Geophysics Education Award Committee, 2003-2005

SELECTED PUBLICATIONS

McDonnell, J., deCharon, A. and Peach, C., "Using Ocean Observing Systems in the Centers for Ocean Science Education Excellence (COSEE)", The Earth Scientist, p. 25, vol. 26, (2010)

Franks, S., J. McDonnell, C. **Peach**, E. Simms and A. Thorrold (2006) Education and Public Outreach: A Guide for Scientists, *Oceanography*, 19(4) http://www.tos.org/epo_guide/index.html

Huntoon, J., **Peach**, C.L. and Hopkins, J. (2005) Geoscience Education and Diversity: Vision for the Future and Strategies for Success. Report of the 2nd Geoscience Education Working Group, September 2005, http://www.nsf.gov/geo/adgeo/geoedu/GEWGII_Report_sept_2005.pdf

Franks, S.E.R., C.L. **Peach**, J. McDonnell and A. Thorrold (2005) Broader Impact: Guidance for Scientists about Education and Outreach, *Eos Transactions* ***86*** *(12), American Geophysical Union.*

Peach C.L. and Mathez E.A. (1996) Constraints on the formation of platinum-group element deposits in igneous rocks. *Econ. Geol.* **91**, 439-450.

SYNERGISTIC ACTIVITIES

Cheryl is the Director of Scripps Educational Alliances, a position focused on supporting the interplay between science and education at Scripps Institution of Oceanography. Cheryl's primary role is to spearhead new initiatives in outreach and education, as well as incorporate aspects of Scripps research activities into high quality education and outreach programs locally, regionally and nationally. She is also Scripps PI for the Center for Ocean Science Education Excellence – California and past Chair of the National COSEE Council, co-PI on the Scripps GK12 program, *Scripps Classroom Connection,* Education Manager for the Ocean Observatories Initiative (OOI) Cyberinfrastructure Implementing Organization (CI) and a founding member of the OOI Education and Public Engagement Team. Cheryl served a three-year term as the Education and Diversity subcommittee Chair on the NSF Geoscience Directorate Advisory Committee. She chaired the 2004 Geosciences Education Working Group and co-authored the resulting report. Prior to her arrival at SIO, Cheryl spent 7 years as an Oceanography Faculty member and Interim Dean at Sea Education Association. At SEA, Cheryl served as a seagoing research scientist and taught college undergraduates both on shore and at sea. Cheryl was P.I. for *Research at SEA*, a 5-year, National Science Foundation, teacher professional development program for middle and high school science teachers. The *RAS* program focused both on providing a research experience for teachers and bringing inquiry-based learning into the classroom. As Interim Dean at SEA in both 1997 and 2000-2001, Cheryl assumed an administrative position that involved interacting with students, parents and employees, providing academic guidance to the faculty and developing new programs.

COLLABORATORS

Collaborators: Craig Strang and Catherine Halversen, Lawrence Hall of Science, UC Berkeley; Janice McDonnell and Oscar Schofield, Rutgers Univ.; Linda Duguay, USC; Annette deCharon, Univ. Maine; Mike Senise, San Diego Unified School District; Peter Tuddenham, College of Exploration; Alan Chave, Woods Hole Oceanographic Institution; Anthony Koppers, Oregon State University; Gail Scowcroft and Dwight Coleman, University of Rhode Island, Graduate School of Oceanography; Ivar Babb, University of Connecticut; Ruth Krumhansl and June Foster, Educational Development Center; Thesis Advisors: Edmond Mathez, American Museum of Natural History; David Walker, Columbia University.