OCEANOGRAPHY PROFESSIONAL DEVELOPMENT IN VIRGINIA VIA COLLABORATION, FIELD INTEGRATION, AND INQUIRY

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Abstract

Seventy-nine in-service teachers completed one of six sections of a grant-funded, graduate-level, summer course entitled, *Oceanography*, that was offered at four different locations in Virginia between 2005 and 2007. The majority of the teachers enrolled with the objective of obtaining their add-on earth science endorsement through the Virginia Earth Science Collaborative (VESC). *Oceanography* was designed to integrate the following: 1) the ocean science disciplines of geology, chemistry, physics, and biology; 2) inquiry-based learning strategies, quantitative activities, and technology; and, 3) Virginia Institute of Marine Science (VIMS) field experience with classroom experiences. These design themes were informed by ocean science content standards and science education best practices, and supported the goal that, upon completion of the course, teachers would be confident and competent in their abilities to teach oceanography concepts to grades 6-12 [1-3]. Learning outcomes, instructor feedback, and participant feedback suggest that the VESC's *Oceanography* can serve as an instructional model for teacher professional development in oceanography. A collaborative instructional framework (marine educators, master teacher, and university faculty), small class size, and end-of-course field synthesis projects are additional elements that contributed to positive learning outcomes in course sections. The primary challenge in the course was the compressed, two-week time frame of face-to-face instruction.

Introduction

The Virginia Earth Science Collaborative (VESC) is a partnership of nine institutions of higher education, non-profit organizations, and more than seventy school divisions. It was funded through a 2005 competitive Mathematics and Science Partnership (MSP) grant [4]. The overarching goal of the VESC was to develop and implement five earth science courses, totaling eighteen credits, to enable secondary teachers to acquire an add-on earth science endorsement. A 4-credit, two-week, graduate-level summer course, entitled *Oceanography*, was among those developed and was offered a total of six times between 2005 and 2007 at four institutions as part of the VESC (see Table 1). The objective of this article is to provide a description of the oceanography course design themes and instructional elements, a participant profile, and a summary of assessment data on learning outcomes and on instructor and participant feedback.

Course Design

The Virginia Department of Education (VDOE) characterizes intensive professional development by continuous, rigorous, and concentrated learning activities. The VDOE states that intensive professional development should:

> ...involve participants in more than basic lecture-style learning experiences. Complex experiences, including problem solving issue analysis, research, and systematic investigation should be a core component in the overall program. The rigor of the activity should demand more of participants than simple comprehension of the concepts presented. Teachers should be involved in applying the content and skills [5].

The VESC course, *Oceanography*, was designed after this model and informed by content standards and by pedagogical best practices that emphasize learning by doing, guided-inquiry, and collaborative learning. The recent publication by the National Research Council entitled, *How People Learn*, recognizes that people construct a view of the natural world through their experiences and observations [2]. To explain phenomena and make predictions, people (including teachers) need to draw from their own authentic experiences and observations—they need to engage in deliberate practice in order to promote a conceptual change of prior knowledge. Authentic data collection and analysis is designed for participant inquiry, thus fostering the development of the skills of observation, data interpretation, and synthesis; this, in turn, exemplifies theoretical and empirical best practices for student learning. It models how scientists acquire conceptual knowledge, since scientific practice *is* itself inquiry [2, 3]. Collaborative working groups, or scientific "sense-making" communities, also model the nature of science: discoveries and scientific connections are rarely made in isolation, but are the fruits of collaboration [6, 7].

Within this framework, faculty and staff at James Madison University (JMU), George Mason University (GMU), the MathScience Innovation Center (MSiC) , and the Virginia Institute of Marine Science (VIMS) collaboratively developed the VESC course, *Oceanography*, around the following three central design themes:

1) Integration of the ocean science disciplines of geology, chemistry, physics, and biology;
2) Integration of inquiry-based learning strategies, quantitative activities, and technology; and,
3) Integration of VIMS field experience with classroom experience.

The goals of the collective design themes were to model the nature of ocean science and ocean science education and to serve as a scaffold for specific elements of the course—elements that may differ slightly from location to location given the background, interests, and teaching styles of the oceanography instructors in the VESC. It was hypothesized that, by staying true to these common design themes, participating teachers would be enabled and empowered as teachers of ocean science content: enabled because the teachers would become competent in the subject area and would become familiar with resources and strategies for teaching it; and, empowered because their confidence level would increase as they took ownership over topics and resources through their inquiry-based field and lab experiences.

Embedded content, and pedagogical and technological learning goals for the participating teachers drew on Virginia *SOL* expectations for secondary earth science teachers. The course content learning goals were for participating teachers to learn the oceanography content identified in the specific *Science Standards of Learning* 1, 2, 3, 4b, 7ade, 8bc, 10a, 11, 13d and the related Curriculum Framework, and the ten Essential Knowledge and Skills (EKS) for oceanography from the *Science Standards of Learning Sample Scope and Sequence—Earth Science* [1, 8]. The pedagogical learning goal was for teachers to be able to identify inquiry-based learning strategies appropriate for oceanography content and aligned with *National Science Education Standards* A, B, and E [9]. The technology learning goal was for teachers to identify technology tools appropriate for oceanography content and integrate technology with content instruction. The course design themes and goals were outlined for the participants in the course syllabi. As a result, the participants knew not only what we were going to do in the course, but also why it was important.

Course Instruction

Course instruction in each of the *Oceanography* sections was largely a team effort (see Table 1). While on campus, the instructional team typically included Ph.D. university geoscience or general science faculty as the primary instructor, assisted by a Teacher-in-Residence (TIR) or master teacher. During the field component, the instructional team expanded to include VIMS marine educators and researchers. The collaboration of university faculty, Teachers-in-Residence, and marine educators typically provided a well balanced mix of content and pedagogical expertise with the additional benefit of maintaining high instructor-to-participant ratios.

The importance of including either a Teacher–in-Residence (GMU and JMU) or co-teaching with a science educational specialist (MSiC) was consistently identified as a key element in the JMU, GMU, and MSiC course sections [12]. The Teacher-in-Residence filled both the roles of a liaison between university faculty and teacher participants, and that of a mentor to the teacher participants. In these roles, s/he simultaneously could assist the primary instructor in keeping the learning bar high, yet realistically grounded.

The collaboration and continuum of VIMS field instructors in *Oceanography* served to standardize course instruction in the field, and drew on the expertise of the VIMS faculty and staff who are most familiar with the Eastern Shore field setting. This also brought in a significant biological oceanography perspective, as the VIMS researchers and educators are primarily marine biologists.

In addition to the formal instructional team, informal instructional collaboration via short-term guest lecturers is noteworthy as well. One of the benefits of hosting a course (or part of a course) on a university or research campus is that discipline specific research experts are accessible and are often amenable to sharing their research with educators. By tapping this informal instructional pool at GMU, JMU, and at the VIMS field station, the teaching and learning experience expanded in both breadth and depth.

Table 1
VESC *Oceanography* Course Offerings and Instructional Team

Year	**Course Location**[1]	**Instructional Team**		
		Primary Faculty Instructor	**Secondary Instructor/Assistant**	**VIMS Marine Educators**
2005	James Madison Univ.	Dr. Kristen St. John	-	Ms. Vicki Clark Ms. Carol Hopper-Brill Dr. Rochelle Seitz
	George Mason Univ.	Dr. Randy McBride Dr. Rick Diecchio	Ms. Marty Lindeman Dr. Donald Kelso	
2006	James Madison Univ.	Dr. Kristen St. John	Ms. Debbie Faulkner	
	MathScience Innovation Center (formerly Mathematics & Science Center)	Mr. Steve Oden	Mr. Chris Lundberg	
2007	James Madison Univ.	Dr. Shelley Whitmeyer	Ms. Debbie Faulkner	Ms. Vicki Clark Ms. Carol Hopper-Brill
	UVA Southwest Center	Dr. Mary Quinlin		

[1] All courses also included three-day field component at VIMS Eastern Shore Laboratory in Wachapreague, VA.

Instructional Resources and Materials

The course materials used were section specific, but typically included a combination of undergraduate oceanography text(s), on-line public access materials, and password-protected, on-line course support, such as *Blackboard*® (JMU) or *Moodle*™ (MSiC). Realistically, participating teachers could not read a complete text in two weeks; however, the text served as a reference during the course, and continues to do so now that the participants are teaching oceanographic material to their own students. Public access materials generally focused on authentic data sets for lab and field activities, such as the tide tables for Wachapreague and NOAA estuary physical property data, or accessing classroom-tested oceanography activities [13-15]. Password-protected, on-line support systems allowed participants to access lecture materials, activities, discussion boards, field trip data sets, links to useful websites, and to post their own contributions (e.g., homework, field trip digital photos).

Daily Schedule

A representative daily schedule for *Oceanography* is shown in Table 2. The day-to-day progression of the content focus followed the logic of first building the ocean basins (geological oceanography), filling the oceans with water (chemical oceanography), and then allowing the water to move (physical oceanography). Next, the ocean waters were populated with life (biological oceanography), followed by an exploration of sediment archive of past oceans (a return to geological oceanography). Each of these topics addressed middle school and high school Virginia *Standards of Learning* (*SOL*) [16]. Depending on scheduling constraints (dorm availability and instructor availability) at the VIMS field station, the field experience for each section could fall anywhere within the two-week meeting time. Content-related active learning strategies were employed every class meeting day.

Table 2
Expanded Daily Schedule, Example from JMU 2006

Date	Content Topics	Secondary and Middle School (Grade 6) *SOL*	Active Learning Strategies
Thurs. July 6	Pre-assessment of content knowledge Build the Ocean Basins: physiography and plate tectonics	ES1bce, ES2, ES3, ES8c, ES11d; Sci 6.1.	Standardized pre-test Gallery Walk; Shoebox bathymetry activity; *Our Dynamic Planet* (CD); Contouring exercise; Plate tectonics (DSDP 3) exercise.

Fri. July 7	Fill the Oceans with Water: navigation, physics, and chemistry of sea water	ES1, ES2, ES3ad, ES11abc; Sci 6.1, 6.4g, 6.5, 6.7eg.	Navigation exercise, differential heating experiment; NOAA activity (T,S, DO – estuaries), intro to probe ware.
Mon. July 10	Field Lab at VIMS, Wachapreague, VA; depart JMU at 9 A.M.	ES1, ES2, ES3, ES4b, ES7, ES9f, ES13a; Sci 6.1, 6.3, 6.5, 6.7, 6.8h, 6.9.	Comprehensive field observation and data collection (e.g., depth, salinity, temperature, DO data collection, secchi disk, dredge and trawl; classify collected marine organisms; sediment collecting, measure tidal range and observe longshore current; barrier island field trip, beach profiling; marine ecosystem exploration), laboratory work, lectures and activities.
Tue. July 11	Field Lab at VIMS, Wachapreague, VA		
Wed. July 12	Field Lab at VIMS, Wachapreague, VA		
Thurs. July 13	Return to JMU; depart VIMS at ~11 A.M.		
Fri. July 14	Motion in the Ocean: surface water and deep water currents, upwelling & downwelling, monsoons	ES1c, ES3ab, ES11ac, ES13d; Sci 6.1, 6.3abc, 6.5	Overlay of winds and currents demo; Coriolis demo; thermohaline circulation activity; continents and currents activity.
Mon. July 17	More Motion in the Ocean: waves, tsunamis, tides, and coastal erosion Begin Life in the Sea (see below)	ES1ac, ES4b, ES8b, ES11abce; Sci 6.1, 6.3abc, 6.5, 6.8h	*The Beaches are Moving*; Wachapreague tide activity.
Tue. July 18	Life in the Sea: general controls, marine habitats, productivity The Archives of the Oceans: marine sediments, depositional provenances; sea level, paleoclimates	ES1b, ES11ab; Sci 6.1, 6.7eg ES1be, ES2, ES8b, ES10a, ES11ac; Sci 6.1	Aurora, N.C. marine fossil activity (regional sea level change); introduction to SOR resources.
Wed. July 19	Post-assessment of content knowledge		Review time; standardized test.

In-Class Laboratory Experiences

Oceanography laboratory experiences were integrated into the daily schedule of the course. These included a mix of exercises that help develop conceptual models of ocean conditions or processes (e.g., modeling of thermohaline circulation) and exercises that develop analytical skills and/or integrate real data (e.g., *Dynamic Planet* exercise, NOAA estuary exercise [17-19]). To model practices that could be replicated by the teachers, the exercises used required materials that could be obtained at discount retail stores, or data sets from on-line resources. In addition, instructor-developed or instructor-adapted paper-and-pencil exercises were frequently included, and in some course sections, lab activity books (e.g., Leckie and Yuretich's *Investigating the Ocean*) supplemented the text [20]. Such exercises were particularly appropriate for quick engagement into a new topic [10-12, 20]. All exercises could be directly translated or adapted for used in a secondary earth science classroom.

Field Experiences

A three-day, shore-based, and offshore (small boats) field trip to the Virginia Institute of Marine Science's Eastern Shore Laboratory was central to all sections of this course [21]. This was not a "show-and-tell" field experience, but essentially a collective research project for the team of teachers. Each section required some form of field-related follow-up project, such as the production of a virtual field trip guide, by each of the teachers as a capstone assignment after the face-to-face meeting time was completed.

During the field experience, teachers were responsible for collecting the minimum following data from three to four sites in a transect from the tributaries feeding the estuary, to the middle of the estuary, and ending in the coastal Atlantic Ocean: latitude and longitude (GPS coordinates), surface current direction and estimated speed, water depth, photic zone depth, dissolved oxygen profile data, temperature profile data, salinity profile data, pH profile data, nutrient data, descriptions of the planktonic, nektonic, and benthic life, and a description of the sea floor sediment texture and composition (see Figure 1). Such data were collected using a combination of oceanographic sampling tools: dredges, trawls, plankton nets, electronic probes, weighed lines, secchi disks, Niskin bottles, and baby box corers. Data collection was a team effort, and the suite of data was compiled by the teachers for use in their individual follow-up projects.

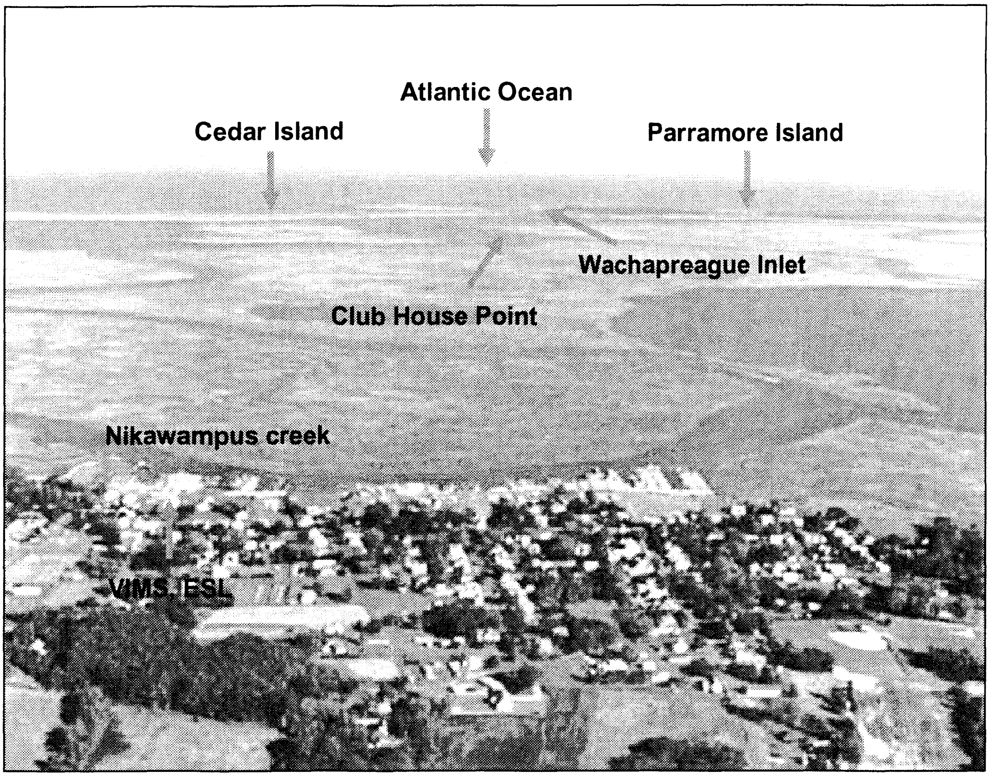

Figure 1. Overview of field location (photo courtesy of VIMS and Steve Oden, MSiC).

In addition to the marine transect sites, visits were made to an exposed mudflat and two strikingly different barrier islands. In 2006, the geologic component of the field experience was expanded to include a detailed transect across Cedar Island, during which teachers collected data to create a scaled profile of this barrier island showing elevation changes, and sediment and vegetation changes from the estuary to the open ocean side of the island.

While at the VIMS Eastern Shore Laboratory (ESL), the teachers also had access to the laboratory facilities. The biological specimens that they collected at the field sites were examined further in the lab to observe their form and function in aquariums and under microscopes. Photomicrographs of the specimens were taken which many teachers included in their field guides. Water samples brought to the lab underwent phosphate and nitrate analyses by the teachers, and sediment samples were sieved and examined under microscopes for textural and compositional categorization. Tours of the VIMS facilities and interactions with visiting researchers completed the field experience and provided the teachers with an appreciation of the ongoing scientific studies on the coast of Virginia, complimenting their own investigation into the nature of the near shore marine environment.

Participant Demographics

The 2005-2007 registration data provide information on the demographics of the teachers enrolled in sections of *Oceanography* (see Table 3). This is supplemented with pre-course survey data from two sections (JMU in 2006 and MSiC in 2006) [11,12]. Given the data available, the majority of the teachers that registered for *Oceanography* were within the first five years of teaching, although some were older adults who had come to the teaching profession as second careers. While 30-43% were currently teaching earth science, they were not endorsed or certified to teach in the subject area. Most teachers were certified to teach another high school science (usually biology) and were taking the courses for their add-on earth science endorsement. There was a second population of teachers registered who taught middle school science and were either also seeking endorsement in high school earth science, or were taking *Oceanography* in particular because ocean science content is part of the sixth grade curriculum.

Table 3
Participant Demographics for *Oceanography* Course Sections 2005-2007

Course Section	Number of Participants (Male: Female)	Grade Level Currently Teaching	Current Licensure Area[1]	Current Primary Subject[2]
JMU 2005	14 (5:9)	14% middle 86% high school	35% biology 65% other	43% earth science 36% other sciences or math 21% other non science
GMU 2005	11 (5:6)	36% middle 64% high school	36% biology 54% other 09% none	36% earth science 54% other sciences or math 10% other non science
JMU 2006	9 (4:5)	33% middle 67% high school	56% biology 44% other	33% earth science 67% other sciences or math
MSiC 2006	20 (5:15)	40% middle 60% high school	50% biology 45% other 5% none	30% earth science 55% other sciences or math 15% other
JMU 2007	12 (2:10)	17% middle 83% high school	67% biology 33% other	42% earth science 50% other sciences or math 5% other non science
SW VA 2007	13 (6:7)	54% middle 46% high school	54% biology 46% other	38% earth science 54% other sciences or math 8% other non science

[1] Other licensure areas included: earth science, chemistry, counseling, physics, elementary education, special education, social studies, and international studies.

[2] Other non science includes: special education, English, not teaching, or not provided.

Evaluating the Impact

Assessment of learning gains was multifaceted. A common pre-/post-test of content knowledge was developed for all VESC oceanography courses by the course development team, and in-class and homework assignments were also used for learning and assessment. The assessment instrument was developed based on the foundational concepts of oceanography that the instructional team collaboratively identified. These concepts all related to the content learning goals of the course and to the ten Essential Knowledge and Skills (EKS) for oceanography from the *Science Standards of Learning Sample Scope and Sequence—Earth Science* [8]. Content areas assessed were largely unchanged from 2005 to 2007, and reflected the stated content learning goals. For five of the six sections, the programwide mean pre-test score was 43.86%, whereas the programwide mean post-test score was 79.82%. These sections showed gains in participants' oceanography content knowledge; mean pre-test to post-test gains ranged from 18.00 % to 61.60%, depending on the course section. It should be noted that, in one of the course sections, the instructor used a different pre-/post-test and these scores are not included in the aggregate; however, positive achievement gains occurred in this section. Synthesis end-of-course projects were additional measures of teacher learning. Such projects typically required the integrated content knowledge with technology rich field experience. One example is the teacher-generated Field Guide Report required of all sections in 2005-2006 [11]. The inclusion of tables and/or graphs of the data collected during the field experience were expected, as were digital images documenting the field trip. Due to the teamwork nature of data collection during the field experience, each participant had access to the same suite of data (and digital images), but the reports are not identical because each teacher had to individually synthesize, interpret, discuss, and present.

Another follow–up assignment had the goal of integrating content knowledge, inquiry learning, real-world data sets, and technology. Such projects involved the creation of new and/or assessment of existing *Oceanography* activity lesson plans. The rationale behind this type of project was that learning where and how to identify good, already available resources for teaching oceanography concepts is essential for teachers new to the subject. Such projects help participants develop a resource base of grade-appropriate activities, which was augmented by participant posting of these resources on electronic classroom support programs, such as *Blackboard*® and *Moodle*™.

Collectively, the content pre-/post-tests, and the follow-up projects and activities were the tools to measure whether the *Oceanography* course objective was met. It is hypothesized that the outcomes of the synthesis projects also *forecast* the teachers' potential for translating the knowledge and skills gained for teaching oceanography in their own classrooms. However, while these may be used to predict the impact on student learning in their classrooms, it does not assess it. Determining the long-term outcomes for the teachers and their students should be a long-term goal of the VESC instructional and evaluation team.

While content pre-/post-test assessment was standardized across the course sections, participant perception (attitude) surveys were administrated only on a section-by-section initiative. The sections taught in 2006 paid particular attention to pre-/post-participant perceptions, and the data from these can be found on-line at the VESC website [11, 12]. Overall, these 2006 perception responses indicate teachers were pleased with their own performance, that of the instructor, and the course sections as a whole. Particularly valued by the participants were the integration of field experiences in the course design and the inclusion of inquiry-based teaching strategies, as evidenced by the following representative comments by participants:

- "The field experience: I have never had and may not have again the hands-on, practical, real-world experience with an estuary where there is so much contrast in all areas of oceanography over such a small geographic area."
- "The lasting value of this class is that it gave me a better understanding of what to condense, expand, or replace in my classroom curriculum. Also, I learned how enjoyable and effective discovery-based learning can be for the students. I intend to change the focus of my teaching methods to one based more on discovery. This will improve the interest level of my students while increasing their confidence in their ability to understand/solve problems."

The Greatest Challenge

Based on instructor, and formal and informal participant feedback, the primary challenge of the course was its compressed time frame [10-12]. A two-week summer course, with approximately eight hours per day of face-to-face contact, is fast paced and highly demanding. By comparison, *Oceanography* was a sprint rather than a marathon. This intense academic experience can lead to some intellectual saturation and fatigue among instructors and participants alike. The potential impact of this on learning outcomes is difficult to assess, but it was at least partially alleviated by the synthesis projects (e.g., virtual field trip reports, lesson plan development), with the deadlines typically placed three to four weeks after the primary face-to-face meeting block was completed. This lag time allowed participants the time to reflect on, apply, and demonstrate what they learned to themselves and to the instructors. The compressed time frame had some benefit: it provided teachers with the opportunity to take multiple summer courses for the add-on endorsement in the same summer. Of the seventy-nine VESC *Oceanography* participants, 58% were also enrolled in other VESC courses. In addition, the compressed time frame also enabled participants to limit their time away from home and family, should they be residing on campus during the course.

Application to the Secondary Classroom

Applications of *Oceanography* to the secondary classroom are fivefold. The content material transfers directly to Virginia *SOL* for oceanography as well as other earth science *SOL*. Second, all classroom activities can be used either in the classroom without any modification, (e.g., thermohaline circulation lab) or they can be adapted for high school classroom use (e.g., NOAA physical properties of estuaries exercise). Third, the outcomes of the field activities applies to the secondary classroom, in that the synthesis field guides developed by the teachers provide images—a virtual field trip—that their students can explore, as well as authentic data sets that can be used in teacher-generated exercises on topics such as tides, temperatures, and salinity distributions. Fourth, teachers made independent steps toward integrating their new content background in oceanography with secondary education through capstone projects involving lesson plan development and assessment. By identifying, reviewing and sharing existing on-line activities that they would use in their classroom, the teachers have begun to build their classroom resource base. Finally, the pedagogy and teaching strategies employed by the instructor aimed to model best practices for the participating teachers, which should in turn, be transferred to the secondary classroom.

Conclusion

Teachers in Virginia have the advantage of living in a state with diverse geology, from the Appalachian Mountains in the west to the shore of the Atlantic Ocean in the east. Facilitators of professional development earth science programs may best serve educators and their students when these facilitators model best practices and integrate data-rich, inquiry-based field experiences into our teacher programs. The VESC's *Oceanography* is but one example of this approach. In addition, by raising the bar on the types of field experience—moving away from show-and-tell toward direct inquiry, data collection, teamwork, interpretation, and synthesis—science teachers are no longer only teaching *about* science, they are themselves *doing* science. In the end, this achievement of active teacher learning now becomes the goal for their own classrooms. ■

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