

THE OFFICIAL MAGAZINE OF THE OCEANOGRAPHY SOCIETY

Oceanography

CITATION

Peach, C., and G. Scowcroft. 2016. Broadening the impact of graduate education in the ocean sciences. *Oceanography* 29(1):60–66, <http://dx.doi.org/10.5670/oceanog.2016.14>.

DOI

<http://dx.doi.org/10.5670/oceanog.2016.14>

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Broadening the Impact of Graduate Education in the Ocean Sciences

By Cheryl Peach and Gail Scowcroft

ABSTRACT. Ocean sciences graduate students are embarking on an increasingly wide array of career pathways that require teaching and/or communication skills. Traditional graduate training currently does not provide many opportunities for students to gain these skills. Graduate education in ocean sciences should evolve to prepare students with not only research expertise, but also the broader skill set essential for success as a twenty-first century ocean scientist. Within academia, increased competition for limited positions is driving an expectation that competitive candidates will have demonstrated teaching experience or training. Outside of academia, communication and outreach skills are required for collaborating with nonscientists within industry or government, reaching out to stakeholders, and addressing policymakers. Creating graduate programs that effectively integrate research training with teaching and development of communications skills helps graduates compete in an evolving job market. Fortunately, much of the foundation for expanding graduate programs has been established through long-term, targeted investments by the National Science Foundation and other US federal agencies. Leveraging these investments, taking strategic actions at graduate training institutions, and collaborating across activities within the ocean sciences community can support a more multifaceted, integrated graduate education, providing the research, teaching, and communication skills necessary for meeting today's challenges.

THE CHALLENGE

The nations of the world are facing a daunting range of ocean-related environmental challenges, including climate change, declining fisheries, ocean acidification, sea level rise, and coastal development, among many others. As society strives to grapple with these issues and their complex economic, political, and environmental implications, ocean scientists emerging from graduate school are finding an increasingly wide array of potential career pathways, both inside and outside of academia, that require skills not traditionally included in ocean sciences graduate training. Ocean scientists are being asked to teach effectively using up-to-date, evidence-based

pedagogical methods, to convey new research results to colleagues outside of their own disciplines, and to communicate their science clearly to policymakers, educators, students, and the public. Graduate education in ocean sciences needs to evolve to prepare students not only with research expertise, but also with the broader skill set essential for success as a twenty-first century ocean scientist (Handelsman, 2015).

Within academia, increased competition for limited positions is driving an expectation that competitive candidates will have demonstrated teaching and outreach experience, as well as pedagogical skills well beyond those gained through teaching assistant positions (Meizlish and

Kaplan, 2008; Love Stowell et al., 2015; Waldrop, 2015). This trend is a reflection of the fact that universities and colleges are experiencing increasing pressure to improve undergraduate science, technology, engineering, and mathematics (STEM) education to retain STEM majors (National Research Council, 2012a; Kober, 2015). Studies indicate that uninspiring introductory courses are among the reasons cited by high performing undergraduates for abandoning STEM majors (Seymour and Hewitt, 1997; President's Council of Advisors on Science and Technology, 2012), and institutions are looking for new hires who can help them achieve their recruitment and retention goals (Adams, 2002; Bouwma-Gearhart, 2007).

Scientists are also accountable for the broader societal relevance and impacts of their research, both as a formal part of their federally funded research (National Science Board, 2011; National Science Foundation, 2014) and as part of institutional initiatives aimed at reaching out to the broader community. Graduate students who have training and experience in addressing the broader impacts of their research are far better prepared than their less experienced peers for future positions as faculty members and researchers.

Supporting K–12 and informal STEM education and public science literacy are among the most common approaches for broadening the impact of individual research projects. The adoption of the Next Generation Science Standards (NGSS;

NGSS Lead States, 2013) by many states provides a natural outlet for ocean scientists to contribute to improving precollege education. Based on a framework developed by the National Research Council (2012b), the NGSS are K–12 standards grounded in robust education research and focused on college and career readiness. They are not only rich in science content, including more ocean sciences than previous standards, but also include a set of performance expectations for specific science and engineering skills, such as analyzing and interpreting data and developing and using models. A recent Ocean Research Advisory Panel report makes a compelling case for the role scientists play in supporting the implementation of NGSS, particularly with respect to “science practices” (Ocean Research Advisory Panel, 2013), and graduate students are a natural conduit for transferring these skills from the research realm to the K–12 and public science education arena. Scientists’ contributions to NGSS implementation will be pivotal to bridging K–12, higher education, and workforce development.

The new generation of ocean scientists will also need to be part of a global workforce that is capable of addressing growing environmental problems and contributing its knowledge to policy development. For example, the Galway Statement on Atlantic Ocean Cooperation, an agreement between the United States, Canada, and the European Union signed in May 2013, is a governmental alliance intended to advance Atlantic Ocean research, including related Arctic Ocean connections (Goeghegan-Quinn et al., 2013). In addition to specific research objectives, the agreement explicitly refers to the need for ocean science education and the communication of research results to the public.

While teaching may not be an explicit job requirement outside of academia,

teaching, communication, and outreach skills can be important when communicating or collaborating with nonscientists within industry or government organizations, reaching out to stakeholders, or addressing policymakers. These so-called “soft skills,” such as communication, collaboration, and leadership, are considered essential for employment and advancement. For example, in the biotech industry, bench skills were at one time the primary requirement. Now, broader skills are nearly as important, including the ability to present data to different audiences and communicate across disciplines (Smaglik, 2010). New standards are being set in which employers consider participation in outreach and facility with social media as “basics” that should be in every candidate’s CV (Bowden, 2011).

These are only a few examples that illustrate the need for expanded training and experience in ocean science gradu-

ate education. Our challenge as an ocean science community is to find ways to more effectively integrate teaching, communication, and outreach training into our graduate education programs, broadening the scope of graduate training and better serving the needs and career aspirations of the twenty-first century ocean science graduate student.

LEVERAGING FEDERAL INVESTMENTS

Creating graduate ocean science programs that effectively integrate research training with teaching and communications skills development is a tall order. Many ocean sciences graduate programs do not have the “in-house” expertise or are not connected to the training resources needed to provide their students with opportunities to develop these skills. These opportunities can be made more widely available by networking

“We further intend to promote our citizens’ understanding of the value of the Atlantic by promoting ocean literacy. We intend to show how results of ocean science and observation address pressing issues facing our citizens, the environment and the world and to foster public understanding of the value of the Atlantic Ocean.”

Goeghegan-Quinn et al. (2013)

ate education. Yet traditional graduate education programs provide little to no opportunity or incentive for young investigators to develop and hone these skills, and graduate students are often discouraged from deviating from the traditional “research apprenticeship” model during

across institutions to coordinate efforts, share approaches and resources, and connect like-minded faculty, graduate students, and staff. Cross-institutional education and communications networks can help us leverage individual institutional capacity and add value to the ocean

sciences community as a whole. Much as we support graduate students in entering the broader research community through collaboration and participation in professional research societies and networks, so should we support students in their education and communication activities.

“One thing I created on my résumé was a separate category for what I called “Teaching and Leadership Experiences,” because I consider those to be related to one another. I find invariably that I am asked about my teaching skills by industrial interviewers such as large chemical or oil companies, as well as by potential academic employers. I think my teaching experience shows that I am able to communicate.”

Kriste Boering, PhD student in chemistry at Stanford University (Reis, 2000)

Fortunately, much of the foundation for training resources and professional networks has been established through long-term, targeted investments by the National Science Foundation and other US federal agencies. Recognizing a broad set of societal and educational needs and challenges, over the last two decades NSF and other agencies made strategic investments in initiatives that expanded graduate student training in education and communication, created a wealth of supporting resources, and provided myriad opportunities for practical experience in science teaching, communication, and outreach. These initiatives also cultivated important networks of institutions and individuals that collectively comprise the expertise, resources, and infrastructure that can help ocean sciences graduate schools incorporate communication and teaching training into their programs. Examples of such NSF-funded

initiatives with relevance to ocean sciences include, but are not limited to, the National Centers for Ocean Sciences Education Excellence (COSEE) Network; On the Cutting Edge (CE), a program managed by the National Association of Geoscience Teachers and hosted

by the Science Education Resource Center (SERC) at Carleton College; and the Graduate STEM Fellows in K–12 Education program (GK–12). These initiatives, and others, provide a robust foundation for future graduate education programs that can meet the needs of the next generation of ocean scientists.

National COSEE Network

The NSF investment in the establishment of the National COSEE Network was a carefully considered decision by the Division of Ocean Sciences based on input gathered from a broad spectrum of ocean scientists and educators at meetings and workshops in the late 1990s. In 2004, the US Commission on Ocean Policy (USCOP, 2004) validated that decision by stating that a nationally coordinated network for ocean sciences education was necessary. The report cited two national-level ocean education networks

as having “particular importance” for the future: the National COSEE Network and the National Sea Grant College Program. Over the ensuing decade-plus, COSEE has created a robust national network of ocean sciences research and education institutions whose core mission is to facilitate scientists and educators working together to catalyze change in ocean sciences education (Figure 1). Leveraging the interdisciplinary teams built within the network, COSEE has impacted local, regional, and national ocean sciences education efforts by developing courses, workshops, and tools that enhance scientists’ teaching, communication, and outreach skills; providing strategies for increasing the diversity of the ocean science workforce; and supporting scientists seeking to broaden the impact of their research.

Here, we illustrate the breadth of tools, resources, programs, and partnerships that COSEE has created for the ocean sciences community and discuss how a network can help prepare young ocean scientists for their roles as principal investigators and/or professionals who engage in ocean sciences education, outreach, and communication as an integral part of their work (see <http://www.cosee.net>).

Communication and Teaching Support

COSEE scientist training includes courses and workshops in communicating science effectively and offers tools and techniques for deconstructing complex science. Examples include (1) COSEE’s Communicating Ocean Science courses, which have been institutionalized at over 30 colleges and universities across the United States and provide undergraduates and graduate students with training and practical experience in science teaching, communication, and learning theory (Strang et al., 2005); (2) the COSEE two-day Presentation Boot Camps that are offered across the United States to train faculty, researchers, postdocs, and graduate students to communicate and present scientific concepts and research findings more effectively; (3) the Gears

Workshop series, in which participants at professional society conferences (e.g., the biennial Ocean Sciences Meeting) are given tools and strategies for thinking creatively about how their research will impact their education goals and vice versa; and (4) innovative resources such as the online, concept-mapping tool that scientists can use to deconstruct complex content to help them communicate their research to non-expert audiences (DeCharon et al., 2013).

Broadening Participation in Ocean Sciences

Broadening participation of groups historically underrepresented in ocean sciences is in the best interest of the entire ocean sciences community. The next generation of ocean scientists should be prepared with strategies for accomplishing this goal and should have access to networks and organizations that will help these young scientists address this challenge at every stage of their careers. COSEE has established a partnership with the Society for Advancement of Chicanos/Hispanics and Native Americans in Science (SACNAS) to increase the visibility of ocean sciences and ocean sciences academic career pathways at the SACNAS annual meetings. For example, COSEE, in partnership with several SACNAS members, sponsors annual symposia and panels focused on ocean sciences research and related career opportunities. Participation has grown from a dozen students in 2008 to over 100 students in 2014. Facilitated by COSEE, several exhibitors have joined forces to create an ocean sciences “street” in the exhibit hall where students can find many resources, including lists of summer internship and research experience opportunities. Working in the online environment with the Institute for Broadening Participation (IBP), COSEE hosts webinars targeted toward students at different points in their career pathways, providing direct access to academic career guidance, live advice from peer panelists and guest experts, and a

collection of useful resources. Since 2011, COSEE-Ocean Systems and IBP have hosted 19 of these webinars, reaching over 800 participants.

Broader Impact Support

A central COSEE focus is catalyzing long-term partnerships between ocean science researchers and education professionals. The COSEE Network offers a wide array of resources, tools, and programs that support the education and outreach-focused broader impact components of research proposals. Examples include the production of *Education and Public Outreach: A Guide for Scientists* (Franks et al., 2006), designed to help ocean scientists with strategies for satisfying their broader impact requirements, and the COSEE Broader Impacts Wizard, an online tool that provides mentorship for scientists interested in broadening the impact of their research (<http://coseenow.net/wizard>). Early training for graduate students in the practical aspects of education and outreach, including partnering

to implement broader impact activities, benefits both proposal principal investigators, who realize higher quality broader impact components, and graduate students, who are better prepared to make meaningful contributions to society in their future careers.

With continued sharing, collaboration, and dissemination activities such as webinars, workshops, and Network-wide meetings, the resources, programs, and partnerships of the Network provide foundational elements and professional networking that institutions can tap into to enhance their graduate training.

On the Cutting Edge

Established in 2002, On the Cutting Edge is an NSF-funded program aimed at supporting the highest quality undergraduate geoscience education, including the ocean sciences. The CE Professional Development Program provides a wide variety of workshops, websites, and activities for graduate students, early- and



FIGURE 1. Graduate students from the University of Southern Mississippi share their research with teachers as part of a COSEE Gulf of Mexico summer institute.

mid-career faculty, and departments. More than 3,000 faculty, postdocs, and graduate students from over 900 institutions have participated in On the Cutting Edge face-to-face and virtual workshops and community-based research projects since its inception. The program's website has more than 9,000 pages of content and is visited by more than 1,000,000 users annually. Moving toward long-term sustainability, the CE program is currently funded by sponsoring professional societies (National Association of Geoscience Teachers, Geological Society of America, American Geophysical Union), remaining NSF funds, registration fees, and contributions from individuals to the NAGT Professional Development Fund.

This project has had, and continues to have, a significant impact on geoscience education in the United States by integrating learning science with geoscience teaching practices, establishing a culture of information and resource sharing, and providing a collaborative foundation for geoscience instruction (SERC, 2015). On

the CE website, graduate students and faculty can find a wealth of resources and workshop opportunities that support career development from graduate school to early faculty positions. Course design tutorials, strategies for enhancing teaching (e.g., a collection of resources focused on teaching with data, models, and simulations), and extensive guidance on navigating an academic career pathway (e.g., a section on Preparing for an Academic Career) are just a few examples. For example, at Scripps Institution of Oceanography, a graduate seminar course on undergraduate classroom instructional strategies uses the website as a source of material for instruction tailored to meet the career aspirations of the graduate student participants. These carefully designed and tested resources can easily be leveraged by the ocean sciences community, either at individual institutions or through cross-institutional collaborative workshops, as means to broaden the preparation of its graduate students.

GK-12 Program

An overarching goal of the GK-12 program was to provide a model, as well as the opportunity, for institutions of higher education to make changes in their graduate programs by incorporating GK-12 training activities and outreach as a permanent and integral part of their graduate education (Figure 2). GK-12 funding provided a full year of support (tuition, stipend, and fees) for participating graduate students, and stipends for classroom teacher participation. More than 90% of former Fellows participating in a retrospective evaluation of the GK-12 program indicated that their participation improved their abilities in a variety of communication, teaching, and teamwork activities (Abt Associates Inc., 2010). Outcomes for graduate students participating in GK-12 varied with the nature and structure of the project, but most fell within one or more of four general categories: (1) greater understanding and mastery of teaching skills; (2) enhanced communication skills, especially the ability to explain STEM concepts to nonspecialists and nonscientists; (3) increased teamwork and collaborative skills; and (4) improved research skills and understanding of the relevance of their research to society (Stoll and Ortega, 2013).

Now that NSF funding for this program has ended, graduate students' participation in the kinds of activities supported by GK-12 requires an institutional commitment to training and compensation for time spent in classrooms or engaged in educational activities, and/or graduate student support funds that are linked to education and outreach activities as part of a researcher's "broader impact." Notably, several institutions are continuing elements of their GK-12 programs (e.g., Virginia Institute for Marine Science; see sidebar by Hopper Brill, 2016, in this issue, on the institute's GK-12 program) and can serve as models for sustaining graduate student involvement in communication and teaching skills training, while contributing to institutional outreach and community service goals.



FIGURE 2. Scripps Institution of Oceanography graduate student and GK-12 Fellow Sarah Lerch instructs seventh graders at a San Diego middle school. Though it was Lerch who applied to the Scripps Classroom Connection program (Scripps GK-12) as a way to fine-tune her teaching and communications skills, this experience also proved beneficial for her teacher mentor Felicia Ryder. "We're working with great teachers; it's not that they need better teachers to come in and help them," said Lerch. "We're learning how to teach from them and they're benefiting from us by getting our expertise in whatever we research." *Photo courtesy of Erik Jepsen/UC San Diego Publications*

EXPANDED GRADUATE TRAINING PROGRAMS IN OCEAN SCIENCES

The foundational elements for expanded ocean sciences graduate student training in teaching, communication, and outreach already exist within the ocean science and broader geoscience and STEM education communities. If leveraged effectively, the programs that have been developed and refined over more than a decade of federal investment comprise the tools, resources, expertise, and professional networks needed to serve the emerging needs of ocean scientists. Achieving this goal requires strategic actions both at individual graduate training institutions and on the part of the ocean science community as a whole. At the institutional level, graduate education programs should support and incentivize a more multifaceted, integrated combination of training in research, teaching, and communication skills. Education and communications training must be formally established as a legitimate part of coursework and “traineeship” activities, similar to research and teaching assistantships. While both financial and administrative supports are necessary to make such institutionalization feasible, a few examples that are relatively simple to implement at an institutional level include:

- Linking graduate student departmental funding to broader impact activities that include training and practical experience in teaching, communication, and outreach, and encouraging researchers to incorporate these institutional activities in their research proposals to federal and state agencies
- Providing institutional support for courses, seminars, and tutorials that leverage those created through COSEE (e.g., Communicating Ocean Science; BI Boot Camps), CE (e.g., undergraduate course design tutorial), and other programs
- Joining COSEE and other organizations in supporting an organized ocean sciences presence at conferences like SACNAS and funding graduate student travel to participate in these activities

As important as individual institutional commitments are, institutionalization in and of itself is insufficient to bring about the sea change in graduate training envisioned here. Cross-institutional dialogue, collaboration, and networking are required to support long-term, community-wide change within ocean sciences graduate programs. For example, every two years, the Consortium for Ocean Leadership holds a retreat for the deans and directors of ocean sciences graduate programs. These types of meetings are an opportunity for institutional leaders to come up with ways to work together to expand graduate training and avoid replication of effort at each institution. This cooperative approach requires ongoing dialogue between institutions, not just once or twice a year, but on a frequent and ongoing basis, and is best accomplished within the context of a professional network dedicated to ocean sciences education, outreach, and training. Just as fruitful collaboration among oceanographic researchers is dependent on a broad network of scientists connected by their academic training and professional networks, so will collaboration in education, outreach, and teaching benefit from a broad network of institutions and individuals dedicated to improving ocean sciences education at every level.

NEXT GENERATION COSEE

The last decade has seen tremendous progress in the integration of ocean sciences research and education, driven in large part by the catalytic programs and activities of the National COSEE Network. The Network has engaged close to 3,000 ocean scientists and graduate students at its over 375 institutional partners. COSEE has promoted ocean literacy, assisted scientists in achieving broader impacts from their research, and provided training in education, communication, and outreach for hundreds of ocean science graduate students.


As NSF funding comes to a close, COSEE is transitioning to an

independent, global consortium under the same acronym but with a new title, the Consortium for Ocean Science Exploration and Engagement, and is working to create a comprehensive, integrated professional network for ocean sciences education, communication, and outreach that includes support for training of graduate students in the broad spectrum of activities in which they are increasingly expected to be proficient. The new Consortium has been engaged in strategic planning to plot the course for its future. Leveraging COSEE’s resources, capacity, and connectivity, and drawing on the legacy of other NSF-funded programs such as CE and GK-12, the Consortium aims to create an integrated approach to supporting institutional collaboration on ocean sciences education at every level. At the core of COSEE’s next generation are networking among its member institutions and individuals to share effective practices, serving as a springboard to collaboration, and promoting cooperation across the community. For example, in June 2015, COSEE held the first Global Ocean Sciences Education (GOSE) workshop in collaboration with the University of Rhode Island Graduate School of Oceanography and the College of Exploration. Graduate education was a key focus area of the two-day workshop, and participants from 15 nations shared graduate training models and discussed the skill set necessary for twenty-first century ocean scientists (Scowcroft et al., 2015).

Through activities like the GOSE workshop, and many others that build on COSEE’s NSF funding legacy, the Consortium is committed to serving the ocean sciences community and working with its member institutions to develop graduate education programs that will meet the needs of both the this century’s ocean scientists and society.

CONCLUSION

Many ocean sciences graduate students aspire to serve society by helping address local, regional, and global issues

in education, the environment, and ocean policy, among many other issues, as an integral part of their work as professional scientists. Institutions engaged in preparing ocean scientists for their careers must better serve their students, especially the legion of twenty-first century ocean scientists who are increasingly called on to communicate and teach about critical global issues. This new generation of scientists needs the community's support to gain skills that help them to be competitive across a wide range of career pathways and to be responsive to the evolving demands of research and teaching careers. There is tremendous opportunity within the ocean sciences community to leverage its existing network, COSEE, to move beyond individual institutional change. Working cohesively, institutions can provide graduate students with the training and experience that will help them be successful throughout their professional careers, whatever paths they may follow. 

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ARTICLE CITATION

Peach, C., and G. Scowcroft. 2016. Broadening the impact of graduate education in the ocean sciences. *Oceanography* 29(1):60–66, <http://dx.doi.org/10.5670/oceanog.2016.14>.