2016

Moving Forward 21st Century Pathways to Strengthen the Ocean Science Workforce Through Graduate Education and Professional Development

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Moving Forward

21st Century Pathways to Strengthen the Ocean Science Workforce Through Graduate Education and Professional Development

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ABSTRACT. The scope of emerging national and international ocean-related issues facing society demands that we develop broad perspectives on graduate education and training in the ocean sciences. A multifaceted ocean workforce and new kinds of intellectual partnerships are needed to address ocean science research priorities, strengthen our understanding of coupled human-natural ocean systems, engage and inform public policy and management decision making, and increase ocean literacy. Alumni from graduate programs in ocean sciences are following diverse career paths in academia, government, nongovernmental organizations, and industry, and thus can inform us about the diverse skills needed to succeed. The ocean science academic community should build on its current strengths (e.g., multidisciplinary and multi-institutional research and education, international partnerships), and capitalize on what some might view as limitations (e.g., remote, yet inviting, coastal campuses, diversity of ocean science programs), to become an incubator of innovation that will advance the field and strengthen graduate education and training. Partnerships within and among institutions with ocean-related programs, and with professional societies, employers, and others, can help us provide cutting-edge, relevant academic options, facilitate professional development, and proactively position graduates for career paths that reflect and address important societal needs.

The importance of ocean science (used here to be broadly inclusive of marine and ocean-related sciences) and the need for a strong ocean science workforce have never been greater. Human populations around the globe rely on ocean processes, the ecological services and resources provided by the ocean and coastal environments, and the strategic benefits of coastal locations for trade, defense, and industry (National Research Council, 2008; National Ocean Economics Program, 2014). Research, discovery, and innovation by ocean scientists have been critical to advancing scientific knowledge of the ocean environment, its resources, and human effects on them (National Research Council, 2015), and have increased the potential for beneficial use of ocean resources and services, as well as human adaptation to long-term environmental changes. Concurrently, impacts of anthropogenic stressors on the ocean and coasts have grown to the point that they now affect almost all ocean areas (Halpern et al., 2015). Given the array of challenging ocean problems, the need for an ocean science workforce that is prepared to participate in complex science-informed policy development and to become effective resource managers, and that can contribute to the development of an ocean science-literate society, is increasingly apparent. Developing this multifaceted workforce may be among the most pressing challenges for our community.

Is the ocean science community prepared to educate and inform this new workforce? What pathways for graduate students can our academic institutions create either individually or cooperatively to develop a future workforce with the knowledge, training, skills, and competencies needed to meet the societal demands that we will face in coming years? How can the ocean science community innovate now to make a difference in the future? In this article we explore some of the ways the field might be able to build on current strengths to facilitate preparation of the future ocean science workforce. Our focus is primarily on graduate education, which was our charge for this special issue.

THE CLARION CALL

In 2000, on the occasion of the fiftieth anniversary of the National Science Foundation, Arthur Nowell (2000), dean of the College of Ocean and Fishery Sciences at the University of Washington, asked: "Is it our role to provide an intelligent basis for public decision-making about marine and coastal issues as well as the larger context of global environmental issues and issues of science in public policy?" He went on to state: "While we

educate the public about oceanography, we should also listen to the challenges that the public believes are important." Woods Hole Oceanographic Institution (WHOI) dean of the MIT/WHOI graduate program John Farrington (2001) also encouraged broader thinking about the role of ocean science graduate education in serving emerging national and international needs. Recent ocean policy documents, such as those from the National Research Council's Committee on International Capacity-Building for the Protection and Sustainable Use of Oceans and Coasts (NRC, 2008), the National Science and Technology Council's Subcommittee on Ocean Science and Technology (2013), the National Oceanic and Atmospheric Administration R&D Portfolio Review Task Force (2013), and the National Research Council (2015), clarify the pressing need for a workforce that can develop, incorporate, and apply use-inspired basic research (sensu Stokes, 1997) and new knowledge and understanding of human dimensions to ocean science and ocean-related issues, help to inform policy development, prioritize management efforts and increase the ocean literacy of the nation. These documents provide a useful roadmap for the diverse education, expertise, skills, and competencies needed in a future ocean science workforce.

Addressing the decadal research priorities set out by the ocean science community (National Research Council, 2015) will require recruitment of bright students who can be trained in research-intensive doctoral programs where they will have opportunities for postdoctoral training and careers in environments that foster creativity, discovery, and innovation. A focus on use-inspired research will be needed to address the most pressing issues facing society (e.g., National Oceanic and Atmospheric Administration R&D Portfolio Review Task Force, 2013). Expanded interdisciplinary initiatives will be needed to strengthen our understanding of coupled human-natural ocean systems. Scientific advancement and effective policy development will require interactions among economists; social, behavioral, and political scientists; legal and policy scholars; and ocean and other natural scientists working together to assess trade-off options and the motivations for and consequences of change (National Science and Technology Council Subcommittee, 2013). Given the scope of current ocean problems, there will be even greater demands for innovation and creative solutions. To be effective, some future ocean scientists will need education and skills beyond those gained from traditional ocean science coursework and research training that complement and enable new kinds of intellectual partnerships. Other pathways will require competencies that allow scientists to effectively engage and inform public policy and management decision-making processes. Increased public engagement and ocean literacy are critically important and will benefit from ocean scientists who are willing to help establish a basic foundation of science appreciation among the citizenry. Undergraduate education in the ocean sciences has the potential to play an important role in building an ocean literate society (Nowell, 2000), as does informal education. With attention from the ocean science community, societal support for ocean science-informed decision making and for ocean science research will increase as the science and its impacts are better communicated and understood by policymakers and the public.

PROGRAM DIVERSITY IS A STRENGTH

Ocean science academic programs around the United States provide students with a range of choices, especially at the master's level (https://www.mtsociety.org/publications/higherguide.aspx). Available areas of focus include marine affairs, marine biology, marine environmental sciences, resource management, fisheries, policy, law, or more recently, business. Some institutions offer joint or concurrent degree programs, hybrid degrees, and Professional Science Master's programs (Halpin and Read, 2016, in this issue; http://www.sciencemasters.com). Other fields, such as the environmental sciences, view such program diversity as a strength (Vincent et al., 2015). Considering the broad range

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of knowledge, skills, and competencies called for in a future ocean science workforce, the current diversity of master's level programs in the ocean sciences is a strength we can build on. We should also consider new kinds of ocean science-focused doctoral programs that put somewhat less emphasis on research training to allow for more breadth in preparation. Given the complexities of ocean science issues, there is a need for some of the best and the brightest to pursue careers outside of academia, but they will need to be well prepared in areas outside of research.

The master's degree in marine science does open up a wide range of job opportunities outside of academic research. For example, Virginia Institute of Marine Science (VIMS) master's program graduates have successfully competed for careers in all major employment sectors, primarily in the ocean sciences or a closely allied field (Figure 1). Most did not go on to careers in academic settings. Although forecasting workforce demands for graduate-level science degree recipients is difficult at best (Council of Graduate Schools and Educational Testing Service, 2010), the VIMS data collected at the time of graduation indicate strong demand for these graduates.

Traditional and alternative master's level programs are sometimes viewed as competing for resources generally reserved for the research-intensive doctoral track. This view may create an obstacle to trying new approaches. A student's willingness to make a personal investment in education will likely depend on an assessment of the relative earning potential for the degree, employment opportunities, and the time it takes to complete the program. Although the data needed to show the value of a master's degree in the ocean sciences may be difficult to obtain, having data is viewed as critical for graduate program recruitment efforts across a range of fields (Council of Graduate Schools and Educational Testing Service, 2010).

Several of the program models mentioned above open up the potential for partnerships with government, the private sector, nongovernmental organizations, foundations, and donor sponsorships. Working individuals, especially those in government and the private sector, may garner employer support when they are allowed to enroll as part-time students or under other arrangements that give them some flexibility to balance work with program demands. In recognition of the needs of working individuals, Savannah State University adjusts course scheduling as needed to accommodate nontraditional students (Carol Pride, Savannah State University, *pers. comm.*, October 18, 2015). Foundation and other private funding can be obtained for education-related training (Hopper Brill, 2016, in this issue). At William & Mary, those who pursue the joint degree program in marine science and public policy have opportunities for paid summer internships. Other programs, such as Sea Grant's Knauss Fellowship Program, provide bridging opportunities with financial support for graduate students who seek careers in the policy realm (Figure 2).

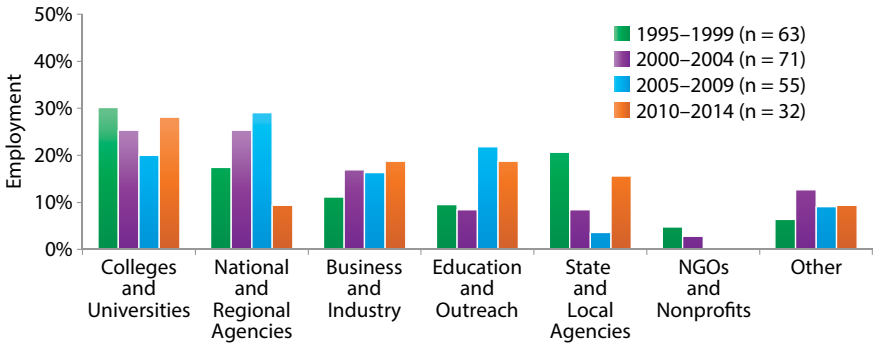

FIGURE 1. Alumni of the master's program of William and Mary's School of Marine Science at the Virginia Institute of Marine Science (VIMS) are employed in diverse ocean science careers. The program awarded its first master's degree in 1943 and its first PhD in 1968, and celebrated the 1,000th degree recipient in May 2015. Students are trained within the context of the Institute's three-part mission of research, education, and mandated advisory service to the Commonwealth of Virginia. Alumni employment in late summer through early fall 2014 was determined using social media, other Web resources, direct contact, or advisor knowledge for individuals who graduated between 1995 and 2014. The graph shows percent of total employment in major sectors for five-year intervals for 221 alumni, excluding those who were still in graduate school (n = 23) and those we could not locate (n = 35). In contrast to the VIMS master's program, most doctoral degree recipients at VIMS over the same period (data not shown) are employed by institutions of higher education in the United States or abroad (56%) in faculty or senior scientist positions, or have careers with government agencies focused on marine environmental research, fisheries management and conservation, and policy development (25%), with most of the remaining employed in the nongovernmental organization/nonprofit sector (6%). Profiles for some of the alumni are available on the VIMS website (http://www.vims.edu/education/graduate/alumni_profiles).

CAREER PATHS ILLUMINATED

Perusal of websites suggests that ocean science graduate programs do a good job of highlighting program options for potential applicants. However, additional quantitative illumination of career paths followed by master's and doctoral degree recipients and the earning potential for different employment sectors in the ocean science workforce would likely help to build student interest in the field. As a former director of a National Science Foundation (NSF)-funded Research Experiences for Undergraduates (REU) program, one of us (LCS) has read the application essays of hundreds of students who were contemplating ocean science careers and has also had an opportunity to interact with many program participants. These exceptionally talented students had already signaled strong interest in ocean science by applying for positions in the program, but they were often unaware of job opportunities both inside and outside of academia. In fact, many graduate students and faculty

remain unaware of nonacademic job options. The lens faculty look through is often still narrowly focused on traditional academic careers. Tracking and reporting alumni placement statistics would allow programs to highlight strengths, encourage potential graduate students to think about career choices at an earlier stage, and also allow students to make better-informed decisions with respect to academic program "fit."

Although we are aware of a handful of programs that have reported alumni placement statistics and some that feature alumni profiles on websites (including our own websites), the information is not readily accessible for many programs. Professional and other organizations, such as the Association for the Sciences of Limnology and Oceanography (ASLO) and Sea Grant, provide career information that could be linked to graduate program websites. Some programs are seeking to track alumni more effectively because job placements impact a school's national rankings (e.g., law schools), development activities, and accreditation assessments. It is also a mechanism for identifying alumni who may be willing to serve as mentors for current students. Social media sites such as LinkedIn are helping in this regard, but often the information is not available to those outside the network.

What can we learn from other professions? All American Bar Association-accredited law schools are required to report employment statistics for graduates at 10 months post-graduation. Many law schools voluntarily report employment data to the National Association for Law Placement, *US News and World Report*, and the *Princeton Review*, since it informs national law school rankings, along with other metrics. To track these data, the William & Mary Law School conducts graduate employment surveys upon graduation. After graduation, various methods are used by the law school's alumni office to identify and confirm employment (e.g., emails, phone calls, searching employer websites, LinkedIn, Google, and reaching out to faculty and classmates).

The earlier we can give students a sense of the suite of competencies—some of which we still need to identify—that will best position them for different professional pathways and the diverse opportunities for employment, the better. In addition to documenting alumni job placement, tracking salaries, satisfaction with the graduate experience, and career satisfaction would allow us to do a better job of assessing the professional preparation of our students and move us past personal experience in helping students pick the right career paths. Greater engagement with alumni can enhance professional development options for our graduate students. Providing venues for mentoring and coaching by alumni can be invaluable to students, exciting for alumni who get to give back, and beneficial to institutions who build stronger ties of support with alumni. Engaging with our alumni and with ocean science employers will help us to evaluate employment trends, strategically build and offer tracks that truly meet the needs of today's ocean science workforce in the United States and abroad, and better anticipate emerging needs. Professional organizations might have a role to play. For example, the American Chemical Society, the American Fisheries Society, and the National Council for Science and the Environment use surveys and other methods to assess what knowledge, skills, and competencies students, university faculty, and employers identify as important to early career success of entry-level professionals (American Chemical Society, 2012; Vincent et al. 2015; McMullin et al., in press). What can we learn from their processes?

US demographics suggest that many older workers will leave the ocean science workforce in the near future, departing not only from universities and government but also from industry. There are also opportunities outside of the ocean sciences that will benefit from employment of individuals trained in ocean science. As educators, we should learn more about them through our alumni and career centers and by networking with employers, from local to international. Ideally, we need to move past thinking that recruitment to the ocean science workforce is only about attracting students to our graduate programs.

INCREASING DEMANDS FOR TRANSDISCIPLINARY TEAMWORK

Involvement of ocean scientists in multi-investigator research teams has enhanced fluency and cross-fertilization across the subdisciplines of the ocean sciences over recent decades (Sharp, 1995; Farrington, 2001). As president of The Oceanography Society (TOS) Susan

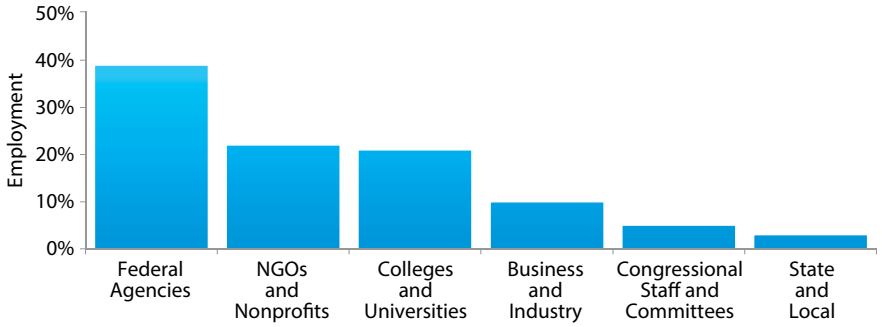

FIGURE 2. The graduates attracted to and successful in the Sea Grant Knauss Marine Policy Fellowship Program are high-performing students with a passion for impacting society. Career information is available from Virginia Sea Grant for 95% of Virginia's Fellows who have completed the program since 1979 when the Knauss program was launched (n = 67). Most alumni of the program are employed in federal government agencies, colleges and universities, and nongovernmental organizations. A small, but notable percentage serve as staff members for Members of Congress or government committees in Washington, DC.

Lozier (2015) recently noted, "Twenty years ago, the concept of interdisciplinary scholarship was suspect, yet today it is heralded as the hallmark of ocean science research." Multi-investigator research programs, such as NSF's Coastal Science, Engineering, and Education for Sustainability (SEES) and Dynamics of Coupled Natural and Human Systems, have begun to integrate natural sciences and social science human dimensions. Building on experiences gained from working within the ocean sciences, investigators have become reasonably adept at building teams within and across institutions. A challenge moving ahead is that working in expanded transdisciplinary teams comes with its own obligations and trade-offs. In addition to the required knowledge base and experience of team members, transdisciplinary programs involve different academic cultures and professional norms, and the accompanying specialized language, theoretical and analytical frameworks and priorities, and professional expectations and practices that tend to isolate our disciplines and make it harder to understand each other (see, e.g., Hackett, 1990; Braxton, 2010; Roach and Sauermann, 2010). More time may be needed to build a proposal team's working relationships. Principal investigators will need advanced project management skills to oversee more complicated financial and staff management; coordinate teams; facilitate synthesis and integration of team, data, and analysis; and communicate the synergistic results and benefits that should emerge. Seeking to promote greater coupled natural-social science inquiries, NSF and other funders are experimenting with program designs and incentives and changing initiatives according to what they learn. Although there may be higher risk of reaching nonconclusive results or for operational breakdowns in these new kinds of teams, working within new intellectual partnerships will provide exciting opportunities for graduate students. Ideally, there will be early consideration of the skills and competencies that students will need to succeed and how our programs can support and enable that professional growth.

BRIDGING KNOWLEDGE AND PROFESSIONAL COMPETENCIES

Ocean scientists are currently employed in all major sectors. They engage with myriad public stakeholders, from children to members of Congress, and from boardrooms to courtrooms. Some ocean scientists are highly engaged in "public scholarship" and its science-to-management extension, others educate youth, and still others advocate for conservation interests. Today's ocean scientists need professional skills to complement their disciplinary expertise. The depth and breadth of the skills required for success vary by career track. While many recent ads for academic positions in the ocean sciences highlight requirements for deep research experience and the potential to excel in teaching, other ocean science career tracks emphasize transferable or "soft" skills, especially the ability to communicate effectively with diverse audiences (Table 1). Other categories of soft skills seen in job announcements (e.g., leadership, interpersonal relationships, collaboration)

TABLE 1. Comparison of job responsibilities, required or preferred areas of disciplinary expertise, and required or preferred skills listed in recent job advertisements for six major career tracks in the ocean sciences. Bold is used to indicate attributes that were highlighted in at least 75% of the ads for a track, and the others appeared in at least 50% of the ads. The ads were obtained from the websites of universities, federal and state agencies and other organizations, listserv announcements, job boards hosted by professional societies, and other sources. Although collected haphazardly, each track includes relevant jobs in academia, federal agencies, government, and nonprofits that span ocean science subdisciplines. N is the number of ads reviewed for each career track. Faculty and postdoctoral positions almost always specified a PhD as the minimum degree expectation, whereas other tracks tended to specify a minimum expectation of a bachelor's degree with additional experience, or a master's degree in lieu of experience.

Position	N	Responsibilities	Discipline	Skills
Faculty	22	• **Research** • **Teaching** • Service	• Ocean science	• Writing for publication • Working in multidisciplinary teams • Research
Postdoc	24	• **Research** • Publication	• **Ocean science**	• Research
Technical Staff	16	• Field studies • Data collection/management	• **Ocean science**	• Communication • Data analysis
Research Program Manager	12	• Administration • Management • Research	• Ocean science	• **Communication** • **Leadership** • Administration/management • Budgeting • Research
Policy Professional	12	• Communication • Policy analysis/development • Leadership • Outreach	• Ocean science, policy, or law	• **Communication** • **Collaboration** • **Interpersonal relationships** • **Policy analysis**
Educator	12	• Informal education • Management	• **Ocean science** or education	• **Communication** • Informal education and outreach • Teaching • Communication products, Web design, and social media

require competencies in active listening, negotiations, project management, fiscal management, dispute resolution, creativity, team building, coaching, and other intangibles. The lack of soft-skill training in STEM fields is a growing concern for many employers (Council of Graduate Schools and Educational Testing Service, 2010).

University programming is responding to the growing need for creative strategies to integrate professional development into graduate curricula in STEM fields, perhaps because the need spans across fields. For example, COMPASS identified hundreds of communication workshops, training, and courses available to students in STEM disciplines (http://compassblogs.org/gradscicomm-list), communication competitions are increasing in popularity (Shaikh-Lesko, 2014), and the use of Individual Development Plans (e.g., Marcus, 2016a, in this issue; http://myidp.sciencecareers.org) as a way to enhance advising and career planning is growing. Read more about professional development opportunities, including the Alan Alda Center for Communicating Science at Stony Brook, and novel approaches at Harvard, MIT, University of Queensland, Florida State University, and others, in Marcus (2016b, in this issue). There are other resources on our campuses that we can utilize to facilitate the professional development of our students. For example, graduate students, teachers, and those involved in informal education or communication with the public may have access to professional development and continuing education programs offered in conjunction with co-located or nearby federal partners, such as Sea Grant and National Estuarine Research Reserve programs.

ENABLING INNOVATION THROUGH OCEAN SCIENCE EDUCATION

Graduate programs in ocean science typically require breadth of training that encompasses the traditional subdisciplines (i.e., ocean, Earth, and environmental sciences) or extends to other allied fields, such as the biological sciences and engineering. Over 20 years ago, Jonathan Sharp (1995) of the University of Delaware Graduate College of Marine Studies noted that breadth in the curriculum is essential for creativity in ocean science research, and scholars who study creativity and innovation in the economy, in science, and in technology have shown that new ideas come from the collision of diverse knowledge and perspectives, often incubated over time (Gruber, 1974; Dunbar, 1997, 1999; Block and Keller, 2009; Johnson, 2010). The ocean science community has an opportunity to build upon its strengths (e.g., willingness to engage in interdisciplinary work, experience with large collaborative projects conducted at sea on lengthy cruises, international research programs, comfort with technology) and capitalize on what might be viewed as limitations (e.g., remote marine labs at a distance from main campuses) to become the incubator of transdisciplinary use-inspired research, education, and innovation. The goal would be to expand the team members even further, to integrate additional physical and natural sciences, as well as social sciences, and maybe even the humanities and arts.

Most universities have the ability to offer courses simultaneously to students enrolled at multiple institutions. The Consortium for Ocean Leadership's Ocean Futures Committee has discussed this strategy recently, and the topic was considered at the 2014 Ocean Sciences Educators' Retreat and by former TOS president Mark Abbott (2014a,b). Teams of educators with specialized expertise can provide integrated courses on a range of topics, thereby increasing diversity in the curriculum, bringing faculty and students with common interests together, and enabling students around the nation, even those enrolled at institutions where there is no ocean science curriculum, to participate in the new, twenty-first century version of the classroom. Although a movement toward such offerings might require our colleges and universities to abandon some of the traditional mechanisms by which students are counted and pay tuition, instructors and institutions receive credit for courses taught, and programs are assessed, these hurdles are not insurmountable. Necessary technical support and facilities are already in place on many campuses, and there are national partnerships for online delivery, such as Coursera (https://www.coursera.org) and other programs.

Skidaway Institute of Oceanography and the University of Georgia, in conjunction with many other institutions around the nation, have recently collaborated on the development and delivery of a special topics distributed seminar-type course, which is offered over the Internet. A dedicated website provides 24/7 access to the readings for each lecture, with lecture slides and a digital recording of the lecture available for review. Any institution or individual can view the lectures, and course credit is available at any institution interested in offering the course. A local faculty member serves as the instructor of record and the course is listed as an offering on each campus. Credit typically varies from one to three credits, depending on the amount of work the professor requires beyond viewing the lectures and reading the provided literature.

The course has been offered twice, first focusing on biology and geomorphology in coastal wetlands (eight institutions and about 75 attendees) and currently focuses on sea level rise and saline intrusion (14 institutions and about 115 attendees). The advantages of this academic approach are many. It leverages the broad reach of accessible technology to make these educational resources widely available. No matter where they are located, students can take advantage of the course, exposing them to material that might not otherwise be available to them. Further, speakers can be recruited who would otherwise not be available to participate in a single classroom, providing the opportunity for students to learn from recognized experts in the fields. The

course is administered by a single host (in this case, the University of Houston; https://sealevelriseandsalineintrusion.wordpress.com/syllabus), which coordinates the lecturers, audience participation, and question-and-answer periods after each lecture. There are other examples of ocean science faculty moving in the same direction that we do not cover here (contact author Schaffner for additional information).

Ocean science and our marine labs could also construct the physical and cognitive space for multiple disciplines and perspectives to exchange ideas, and discuss, contemplate, and solve our most serious ocean problems. While marine labs can be isolated from main campuses and other disciplines, almost universally, other scientists, students, and stakeholders enjoy visiting marine labs; they are envious of our views, our picturesque communities, and our relaxed atmospheres. Marine labs are used quite effectively for teaching specialized courses, bringing students and faculty together for intense learning experiences (e.g., Perry, 2016, in this issue). Getting researchers and advanced students together with enough time for meaningful interactions promotes discussion and the free exchange of ideas, as well as student development and networking—consider also the Gordon Research Conference model. Why not extend this concept further to bring together diverse transdisciplinary groups, including students, at marine labs? Although Nowell (2000) thought that oceanography had, perhaps, missed the chance to take the lead in interdisciplinary education, it is not too late. We need to be bold, to go further than we have in the past. If we do, ocean science can be the university's hub of innovation, solutions, and advancements in knowledge.

FINAL THOUGHTS ON MOVING FORWARD

To the greatest extent possible, we should work together as a community to better understand and engage in larger societal processes, and address the challenges and needs that are essential in decision making related to ocean issues. This is of primary importance for the future well-being of the nation. Active engagement will allow us to better understand workforce demands and, in turn, help to better position our graduates for future careers. Projections of anticipated ocean workforce needs from government agencies and the private sector would be very useful. We see the current diversity of graduate programs available across the ocean community, big and small, traditional and more broadly focused, as a plus. We can learn from what works in other programs (and what doesn't), consider whether alternate pathways are complementary, and in doing so provide a vibrant vehicle for ocean science education. We have opportunities to use the strengths of the ocean science academic community to build innovative educational offerings in cost-effective ways. At the same time, we acknowledge that we have entered a new phase in higher education, one in which faculty and higher administration face increased pressure to show relevancy in what they do and accountability for the educational offerings they provide, and to assess the success of their students, all at a time when state and federal support is at best staying flat. Accordingly, shouldn't we, as a field, work to ensure that our educational offerings are tailored to these changing norms and to changes in societal needs? While we offer here only a few thoughts, mostly drawn from our personal experiences in ocean science higher education, we are well aware that many other aspects of graduate education across the ocean sciences deserve to be highlighted and considered.

> "...shouldn't we, as a field, work to ensure that our educational offerings are tailored to these changing norms and to changes in societal needs?"

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ACKNOWLEDGMENTS

We thank Nancy Marcus, Sue Cook, Chris D'Elia, and an anonymous reviewer for their thoughtful comments on an earlier draft of this manuscript. Linda Schaffner also wishes to recognize the contribution of VIMS graduate student Bruce Pfirrmann who collected and analyzed many of the job ads used to provide the data in Table 1.

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ARTICLE CITATION

Schaffner, L.C., T.W. Hartley, and J.G. Sanders. 2016. Moving forward: 21st century pathways to strengthen the ocean science workforce through graduate education and professional development. *Oceanography* 29(1):36–43, http://dx.doi.org/10.5670/oceanog.2016.09.