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Recommended Practices for Integrating Education, Diversity, and Research

Five Lessons Learned from NSF Science and Technology Centers

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INTRODUCTION

Over the last couple of decades, funding agencies have increased pressure on scientists to demonstrate that their research has some societal benefit. When the National Science Foundation established the Broader Impacts requirement (NSF, 1997) by merging two review criteria—utility or relevance of the project and its effect on the infrastructure of science and engineering—principal investigators largely ignored it (Lok, 2010). Then, in 2002, NSF began to return (without review) any proposal that didn't explicitly address broader impacts (NSF, 2002).

The NSF crackdown was largely driven by workplace development needs—and growing concerns about US global competitiveness—in Science, Technology, Engineering, and Mathematics (STEM; National Academies, 2007). Women comprise 51% of the US population, yet only 23% of ocean and Earth scientists are female. Ethnic minorities (excluding Asians, who are generally not underrepresented in STEM fields) comprise 32% of the US population but only 7% of ocean and Earth scientists (NSF, 2013). Ocean and Earth science positions are projected to increase in the United States by 16% from 2012 to 2022 (Bureau of Labor Statistics, 2012a), compared to a 10% increase in STEM jobs overall (Bureau of Labor Statistics, 2012b). Tapping into a wider and deeper talent pool, regardless of gender or ethnicity, will ensure that the United States remains capable of meeting twenty-first century STEM workforce demands.

NSF's enforcement of the Broader Impacts criterion was a game changer, with many researchers for the first time having to respond to questions such as: *How well does the activity advance discovery and understanding while promoting teaching, training, and learning? How well does the proposed activity broaden the participation of underrepresented groups*? (NSF, 1997)

This article provides practical advice and strategies to help researchers incorporate broader impacts into their research projects by presenting recommendations gleaned from active NSF Science and Technology Centers (STC). Developing and delivering education and diversity programs within the context of STEM research are integral to the STC mission. In this project, a group of STC education and diversity directors pooled their knowledge and experience to compile a list of "lessons learned." As half of the STCs that contributed recommendations are in oceanography or related fields (atmospheric science, remote sensing), these recommendations may be of particular interest to oceanographers and other geoscientists.

METHODS

As a first step, we created a 24-question online survey to systematically collect qualitative data (recommendations) regarding STC education and diversity. Next, we pre-tested the survey with

selected centers to ensure the questions were clear and the online survey system was functioning as anticipated. Then, we invited all 14 active STCs to complete the survey. Ten centers (71%) responded, including five in ocean and Earth science. Finally, we coded the raw data and identified key themes and commonalities, which were then synthesized into summary recommendations.

RECOMMENDED PRACTICES

This paper presents a selection of recommendations that are broadly applicable to academics across science and engineering fields, and shares strategies on how to enact them. We do not summarize all survey results, and particularly exclude those recommendations that are specific to large, multi-institutional centers such as STCs.

1. Develop and maintain partnerships for education and diversity.

Find partners with common interests and goals, and invest in them. Use partnerships to gain advice, leverage resources, and maximize results. Establish win-win relationships; recognize that both sides have to benefit. Nurture long-term partnerships by maintaining regular communication. Move strategically and don't stretch yourself too thin.

How to start: First, do not wait until you have a proposal to submit. Find potential partners and learn as much as you can about them when there is no time pressure. Early communication establishes a foundation for sustained collaboration and maximized impacts. It also conveys genuine interest in broader impacts irrespective of proposal requirements.

To find partners, you could start locally, in your university or community. Consider local schools, science museums, science discovery centers, minority-serving STEM organizations, media outlets, and/or your university's college of education. Ask colleagues for recommendations. If you are new to engaging in community outreach, expect to be surprised by the richness of science education collaborations in your community. Then, well in advance of any deadline, contact potential partners to introduce yourself and gauge their interest. Share your goals and expertise, and be respectful of theirs. If others are not available to introduce you, consider a self-introduction. For example:

I've been reading about your educational (and/or diversity) programs in xx. I'm impressed with your community engagement and your evaluation results. Your work appears to truly excite the community about science. I'm a new assistant professor in xx with little experience in broader impact activities, and I'm eager to partner with the experts. You come highly recommended by my colleague, xx.

My main goal is to broadly communicate my scientific research and why it's important. I want it to matter to the everyday person. If you're interested in learning a little about my research, click here.

I'd really like to learn more about the types of programs that your organization offers, and to explore ways in which we could potentially collaborate. Would you be interested in setting up a meeting or phone call to explore potential collaborations?

2. Integrate diversity, education, and research.

Develop an outreach program designed to communicate your research and broaden participation. Involve both researchers and educators in program development and delivery (see #1 above for partnering with educators). Lead your students and staff in outreach activities and welcome creative contributions from them. Incentivize their participation. Utilize training at your institution or national conferences to increase competencies, and provide "dry runs" to ensure success.

Use a vertical approach (Cozzens, 2008) to integrate diversity, education, and research throughout your laboratory. Don't limit your diversity efforts to pre-college outreach. Keep diversity in mind when hiring students and researchers. Numbers are important to quantify participation, but it is equally important to think beyond numbers. Diversity should encompass equity, access, and inclusiveness. Try to recognize implicit biases. Ask yourself questions like: How often do I collaborate with faculty at minority-serving institutions? Are students reading papers from researchers of diverse backgrounds? Truly integrating diversity into our labs and organizations may require a cultural change, such as accepting different ways of being so everyone can contribute and be successful (see Case Study 1).

How to start: As always, start by doing your homework. Gather benchmark demographic data to see how your lab/department's diversity compares to state and national averages. Gender, ethnic, and racial data for all NSF-funded science and engineering professions, in comparison with census demographics, are available from the NSF website (NSF, 2013). Dig into the science education and diversity literature to learn about evidence-based practices in broadening participation (e.g., BEST, 2004; Pandya et al., 2007; Museus et al., 2011). Then, identify goals and potential partners, and see how you can work together to incorporate these effective practices.

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3. Evaluate your education and diversity programs.

Budget for professional evaluators, and work closely with them. Build evaluation into activity or program design, not as an afterthought. Co-developing programs and evaluations will allow you to think about how the data can be used to drive methods and approaches to evaluation. Focus on both short-term outcomes and long-term impacts, and use a variety of qualitative and quantitative instruments. Utilize national statistics as metrics, and ensure they are specific to your discipline. Use your evaluation results to identify challenges and document successes. Publish your results in peer-reviewed journals (see Case Study 1).

How to start: First, solicit from colleagues or funding agencies recommendations for external, professional evaluators who specialize in science education and diversity. Share your goals, budget, and ideas with potential evaluators and solicit their input. Realize that they may be reticent to invest significant time developing an evaluation plan (e.g., for a proposal) until they have a contract.

4. Develop and maintain an effective Web presence, including Internet and social media.

Hire professionals to manage your website and social media. Ensure your website is accessible, device- and mobile-friendly, and well organized. Include information for both the general public (e.g., your mission, recent activities, and accomplishments) and internal participants (e.g., calendars, documents, and data sharing). Implement security measures as appropriate. Make your website informative without it being too onerous to keep up to date. Use a variety of social media to increase your reach. Realize that social media are the only way to reach certain demographics. The NSF Center for the Study of Information based at Purdue University specializes in the science of information, and we offer its website as an exemplar: http://www.soihub.org.

How to start: Begin by checking out a range of websites and social media that feature scientific research, education, and diversity. Talk to professionals (or teenagers!) to learn the functional differences among various types of social media. For example, Facebook allows current and former participants to stay connected and engaged, while a Twitter feed can share your research activities with the general public on a daily basis.

5. Promote leadership among graduate students and postdocs.

Provide professional development training opportunities based on student/postdoc input and feedback. Reward their participation. Develop mechanisms for students and postdocs to propose their ideas and participate in decision making. Encourage them to participate in the peer-review process of grants and/or publications. Create a student/postdoc council to plan events such as journal clubs and educational outreach. Communicate their successes to a broad audience (see Case Study 2).

How to start: Solicit ideas from your department or college's graduate students and postdocs on a range of topics (e.g., delivering outreach to others, their own professional development needs). Better yet, enlist the support of students and postdocs in creating and administering a survey of their peers. One survey question could explicitly ask for volunteers to serve on a student/postdoc leadership council whose first task could be to analyze survey results.

CONCLUSIONS

The recommendations presented here for incorporating broader impacts into research projects were collaboratively developed by STC education and diversity directors. Some commonalities in

CASE STUDY 1

When the NSF Center for Layered Polymeric Systems (CLiPS) was established at Case Western Reserve University (CWRU) in 2006, staff members set their sights on improving diversity across the center. At that time, the PhD program in Macromolecular Science and Engineering ("Macro") had no minority students. In fall 2014, African Americans comprised 12% of Macro PhD students, which is on par with the national population.

How did they achieve this parity? CLiPS created vertically layered research teams. Within each team, faculty members define and direct the research, and graduate students and postdocs have individual projects. Undergraduates and high school students work together on a graduate student's project, with each student being responsible for a part of the project that is commensurate with that student's level of learning.

Based on recommendations from their science teachers, high school students in the Cleveland Metropolitan School District (CMSD) were invited to participate. CMSD is a challenged, urban school system with a minority enrollment of ~80%. Upon program completion, students are aggressively recruited to enroll at CWRU. Upon college graduation, the undergraduate researchers are again aggressively recruited, this time to the PhD program.

External evaluation professionals were hired to evaluate the high school program. They conducted interviews with teachers, parents, and peer groups; analyzed data on demographics, socioeconomics, and school performance; and administered surveys regarding student interests, habits of mind, and self assessments. The evaluation results led to revised recruitment, curriculum, and program format strategies. One outcome was kick-starting the high school program during the summer, leading to increased student bonding and more efficient curriculum delivery. Of the 81 high school students who began the CLiPS program, 53 have graduated to date. All 53 graduates have entered college, with 83% of them majoring in STEM fields.

CASE STUDY 2

The NSF Center for Microbial Oceanography: Research and Education (C-MORE) based at the University of Hawaii created a Professional Development Training Program (PDTP) for graduate students and postdocs composed of eight core modules: outreach, leadership, proposal writing, science communication, diversity, teaching, mentoring, and research exchange (Bruno et al., 2013a). Before developing the PDTP, we researched existing resources. Many of the newly created modules invoked existing resources to avoid reinventing the wheel. Students, postdocs, and faculty were all actively involved in PDTP development in order to develop a sense of shared investment.

A leadership council of students and postdocs is responsible for planning and facilitating the trainings. To encourage participation, students who complete each module receive a certificate, and training organizers are credited with completing the leadership module.

To supplement the core modules, the leadership council has offered additional professional training opportunities based on student demand. Recent "on-demand" workshops covered topics such as communicating ocean science, networking, fostering research collaborations, and exploring oceanography careers inside and outside academia. In a few cases, council members co-wrote the proposals that funded the training (e.g., Böttjer et al., 2014). Students are encouraged to communicate both in the popular media and in peer-reviewed journals (e.g., Bruno et al., 2013b).

In 2013, the C-MORE PDTP was developed into a graduate-level professional development seminar course in the Department of Oceanography at the University of Hawaii (Guannel et al., 2014).

these recommended practices include: start early (well before any proposal or other deadline), do your homework (e.g., review the science education literature for best practices, learn about existing resources at your institution), partner with professionals (e.g., in education, diversity, website design, and evaluation), and engage all stakeholders (including your students and postdocs). We encourage researchers, educators, and anyone else engaged in broader impact activities to reflect upon these recommendations and discuss them with their students and colleagues. This paper is intended to be a living document, and comments are encouraged.

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