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Diversity and Equity in the Lab: Preparing Scientists and Engineers for Inclusive Teaching in Courses and Research Environments

Lisa Hunter,[1,2,3,a] Scott Seagroves,[1,2,a] Anne J. Metevier,[1,2,a,b] Barry Kluger-Bell,[1,b,c] Lynne Raschke,[4,a] Patrik Jonsson,[5,d] Jason Porter,[6,a] Candice Brown,[c,e] Gabriel Roybal,[1,7] and Jerome Shaw[8]

[1]*Institute for Scientist & Engineer Educators, Center for Adaptive Optics, U. of California Santa Cruz, 1156 High St., Santa Cruz CA 95064*

[2]*Akamai Workforce Initiative, U. of Hawai'i Institute for Astronomy, Advanced Technology Research Center, 34 Ohi'a Ku St., Pukalani (Maui) HI 96768*

[3]*Center for Adaptive Optics, U. of California Santa Cruz, 1156 High St., Santa Cruz CA 95064*

[4]*School of Sciences, College of St. Scholastica, 1200 Kenwood Ave., Duluth MN 55811*

[5]*Institute for Theory & Computation, Harvard-Smithsonian Center for Astrophysics, 60 Garden St., MS–51, Cambridge MA 02138*

[6]*College of Optometry, U. of Houston, 4901 Calhoun Rd., Houston TX 77204*

[7]*Department of Molecular, Cell, and Developmental Biology, U. of California Santa Cruz, 1156 High St., Santa Cruz CA 95064*

[8]*Department of Education, U. of California Santa Cruz, 1156 High St., Santa Cruz CA 95064*

[a]*NSF Center for Adaptive Optics during some of this work*

[b]*independent science/engineering education consultant*

[c]*Exploratorium Institute for Inquiry during some of this work*

[d]*Santa Cruz Institute for Particle Physics during some of this work*

[e]*NSF Center for Informal Learning and Schools during some of this work*

Abstract. Despite high attrition rates in college-level science, technology, engineering, and math (STEM) courses, with even higher rates for women and underrepresented minorities, not enough attention has been given to higher education STEM classroom practices that may limit the retention of students from diverse backgrounds. The Professional Development Program (PDP) has developed a range of professional development activities aimed at helping participants learn about diversity and equity issues, integrate inclusive teaching strategies into their own instructional units, and reflect on their own teaching practices. In the PDP, all participants develop and teach a STEM laboratory activity that enables their students to practice scientific inquiry processes as they gain an understanding of scientific concepts. In addition, they are asked to consider diversity and equity issues in their activity design and teaching. The PDP supports participants in this challenging endeavor by engaging them in activities that are aligned with a PDP-defined Diversity & Equity Focus Area that includes five emphases: 1) Multiple ways to learn, communicate and succeed; 2) Learners' goals, interests, motivation, and values; 3) Beliefs and perceptions about ability to achieve; 4) Inclusive collaboration and equitable participation; 5) Social identification within STEM culture. We describe the PDP Diversity & Equity focus, the five emphases, and the supporting activities that have been designed and implemented within the PDP, as well as future directions for our diversity and equity efforts.

1. Introduction

The fact that science, technology, engineering, and mathematics (STEM) fields are not broadly inclusive of the population of U.S. citizens is well documented (National Science Board 2010; Hurtado, Eagan, & Chang 2010; Hill, Corbett, & St. Rose 2010; PKAL 2006). Although the lack of diversity in STEM fields is not necessarily obvious on a daily basis, and especially not to those in the majority groups, there are reasons for all to be concerned (see for example Tilghman 2003). One can argue that limiting or excluding significant proportions of the population is unjust on moral grounds, even if it is unintentional. The lack of diversity in STEM also means that the talent pool is not fully utilized, limiting our potential, or of even more concern, influencing the problems we choose to tackle. Including broader perspectives and concerns in STEM will lead to not only new avenues of research, but new approaches and new ways to view results. The exclusion of significant fractions of our population (women and minorities) will be limiting in some of these very direct ways, but as Tilghman brought up may also make STEM less desirable to many:

> "Science will look increasingly anachronistic if women and minorities are not participants in the enterprise. As other professions move successfully toward a goal of inclusiveness, science will appear increasingly backward-looking, and will be less attractive to talented students of all types."

While the term "diversity" can apply to a host of differences between people, we focus here on diversity as it applies to gender, race, and ethnicity, and specifically on issues in higher education. A recent report from the Higher Education Research Institute (2010) highlights the problem of retention in STEM at the undergraduate level, a critical transition point in students' path from being interested in STEM to actually advancing into a STEM career. Approximately one third of students from all gender and racial/ethnic backgrounds in the U.S. enter college interested in pursuing STEM. However, many of those students do not graduate with STEM degrees, and either switch to other majors or leave college altogether. For example, of White students who entered college intending to pursue STEM degrees, only 56% ended up with a degree of any kind after five years. On the other hand, of the White students who intended to pursue non-STEM majors, 73% completed a degree of any kind. The attrition rates in STEM are disheartening when compared to other fields of study (and particularly troubling when considering that many who leave STEM also leave college altogether), but the disproportionately higher rates for women, Hispanics, African Americans, and Native Americans is even more concerning. Of the students who entered college with the initial interest in pursuing STEM degrees, 33% of White students and 44% of Asian Americans finished degrees, while only 22% of Latinos and 18% of African Americans completed degrees.

Bringing parity to completion rates for all groups is a national challenge that has implications for both how students are prepared before college, and how they experience STEM in college. Universities play a direct role in the educational outcome of students intending to major in a STEM field. Although there are challenges related to the pre-college preparation of incoming students, there is a clear need to improve the STEM college experience to make it more equitable. Connections between K–12 STEM pedagogy and equitable outcomes are supported with a growing body of evidence (e.g., Thadani et al. 2010; Moje 2007). Inquiry teaching and learning, at all levels, has been called for (e.g., PKAL 2006; AAAS 1989; NRC 2000, 2005a; NAS, NAE, & IoM 2006) as effective and equitable pedagogy. When carefully implemented, inquiry activities employ many inclusive teaching strategies, and evidence for the connections between inquiry and equitable education outcomes is growing (e.g., Wilson et al. 2010).

2. Diversity and Equity in the Professional Development Program

The Professional Development Program (PDP) prepares early career scientists and engineers to be effective and inclusive educators. Through the PDP, participants attend a series of workshops, join a team to design a laboratory activity, teach the activity, and then reflect on their experience. This paper describes the aspects of the PDP related to diversity and equity, including a description of relevant workshops, our challenges, and emphases that have emerged from years of work within the PDP community. A full description of the PDP can be found in other papers (Hunter et al. 2008, and Hunter et al., this volume), but it is important to note that Diversity & Equity is one of three major Focus Areas in the program. The other two areas are Inquiry and Assessment, both of which have significant overlap with diversity and equity, especially in how they are defined within the PDP.

Most PDP participants work toward designing and facilitating undergraduate laboratory activities, and we are oriented toward diversity issues that affect academic laboratory settings, such as lab courses and research environments. Some examples of challenges in the college learning environment include the fact that colleges serve students beyond the local community, students voluntarily attend classes, contact time with students is much shorter than in K–12, and college-level STEM content can be difficult to connect to students' daily life.

While we recognize that recruitment activities are valuable for bringing more students into the STEM "pipeline," and that preparation in K–12 needs attention, we focus more strongly on retaining students currently in the pipeline. Our philosophy draws from a blend of formal research and perspectives from practice, as well as an intentional commitment to focus on a problem that is often neglected. Very generally, we believe that it is possible, by thoughtfully designing and teaching laboratory activities, to have a positive impact on students directly in the STEM learning environment, and that much of what can be applied to classroom labs is easily transferable to research environments.

More specifically, we recognize that learners come to the classroom with diverse educational, social, and cultural backgrounds, and thus they come to the classroom with different knowledge, ways of knowing, and experience with activities. This affects not only the content understandings they bring into the classroom, but also the way that they understand, due to their social and cultural experiences. Their backgrounds also affect their experience, comfort, and skills with scientific processes; their values, interests, and attitudes about STEM; their beliefs about their own competency and intelligence; and the cultural norms they are used to participating in as they communicate and interact with others. Students' backgrounds have an impact on their learning experiences, their academic success, and their entry and retention in STEM. While learners' backgrounds can become barriers to learning and success, they can also provide opportunities to bring in new ideas, new ways of working and solving problems, and new ways of applying solutions. Learning environments — the curriculum, specific activities, interactions with peers and instructors, and the overall learning community — can be created to support diverse learners and equity.

3. PDP Diversity & Equity Emphases

The knowledge base on issues related to diversity and equity spans many disciplines and includes research findings as well as documentation from the practitioner community (those who design and implement programs, interventions, and innovative curriculum). Distilling the collective knowledge down from these disparate sources into practical strategies and educational innovations is challenging, and without a framework, educators often resort to employing strategies without understanding why or when they might work, and then have no structured way to reflect on the outcomes. For many years the PDP staff sought to explicitly include more on diversity and equity within the series of PDP workshops, and struggled to frame disparate research findings and bring practical strategies into workshops in a coherent way. Given the lack of a relevant framework to guide the development of workshops, we formulated a focus based on our teaching interests and went to the literature seeking well-supported research findings that had practical implications (§4 includes descriptions of some of the sessions we developed). Thus the development of diversity and equity content within the PDP was framed by practice, and informed by research.

Diversity and equity considerations have always been part of the PDP, continually becoming more explicitly included, but the articulation of a Diversity & Equity Focus Area emerged from a PDP assessment project. As part of our ongoing work to evaluate the outcomes of the PDP, we were interested in learning about whether PDP participants increased their understanding of strategies they could use to teach more inclusively. We designed a survey prompt that was given to PDP participants before and after their participation in the PDP, and developed a rubric to analyze the results. The rubric consisted of five criteria (or dimensions) that reflected the PDP content related to diversity and equity, which had grown and evolved over time to include research findings that PDP staff found to be compelling and relevant to PDP teaching venues. The analysis of the survey responses, using the rubric, indicated that PDP participants made significant gains in their responses, and is reported in a companion paper in this volume (Metevier et al., this volume). The rubric was immediately useful in structuring our own thinking, and illuminated our need to be more explicit in our intended learning goals for PDP participants. The dimensions of the rubric were revised and became the five emphases of the Diversity & Equity Focus Area.

This evolution of the PDP Diversity & Equity Focus Area makes it clear that it is not a formal framework, nor should it be considered comprehensive in coverage. It is a tool to help the PDP community translate the disparate research on diversity and equity issues into informed practice. The intent of the emphases is to help our community structure their thinking, reflect on their practice, and build a practical knowledge base within the PDP community. PDP participants can consider research findings from the emphases, learn and use teaching strategies informed by the research, develop their own innovative approaches informed by research, and then can share the outcomes within the community. PDP staff use the emphases to develop a coherent set of workshops, identify gaps in PDP offerings, and assess PDP participant progress.

The five emphases of the PDP Diversity & Equity Focus Area are described below. They overlap in multiple ways — in some cases an area of research may be relevant to more than one emphasis, in other cases a teaching strategy is supported by more than one emphasis, and sometimes a learner practice (e.g., communication) is relevant to more than one emphasis. Each emphasis provides a different way to view a learning environment or situation. Much of the research that supports the emphases is broadly applicable, as are the emphases themselves; however, the overall PDP Focus Area made up by these five emphases is most relevant to STEM laboratory environments in higher education.

1. **Multiple ways to learn, communicate and succeed:** Learners should be provided with multiple ways to engage in, approach, and succeed in their work, and multiple ways to communicate their understandings.
2. **Learners' goals, interests, and values:** Learners' goals, interests, values, and sources of motivation should be engaged and leveraged through activities that are relevant, meaningful, and challenging.
3. **Beliefs about learning, achievement, and teaching:** Learners and teachers should develop beliefs about learning, achievement, and intelligence that support an expectation of success for students from all backgrounds.
4. **Inclusive collaboration and equitable participation:** Learners should have equal opportunities to participate and equal access to resources in classroom and collaborative activities. They should have opportunities to contribute diverse ideas, identify problems and solutions, and participate as valued team members.
5. **Social identification within science and engineering culture:** Learners should gain a sense of belonging in the science/engineering culture that fits with who they see themselves as, who they want to become, and what they want to become part of.

3.1. Multiple ways to learn, communicate, and succeed

People have different approaches to learning and participation, and have different repertoires of learning practices and preferences. Furthermore, they communicate their prior knowledge in different ways. Their backgrounds shape how they communicate and demonstrate success, so that success can look and sound very different for different students, and potentially lead to assessment outcomes that favor some students over others (NRC 2002, and references therein). Environments that consider learners' social, cultural, and educational backgrounds, or are "learner-centered" (NRC 1999, 2005b, and references therein), provide multiple ways to learn, communicate and succeed and are more likely to engage a broader range of students. Instructors can anticipate, learn about, and support students' initial learning approaches, and offer avenues for students to build new approaches to learning and participation, expanding their repertoire rather than treating their preferences as static traits (e.g., Gutiérrez & Rogoff 2003). Articulating clear learning goals, and providing multiple avenues for learners to achieve goals and demonstrate success, supports more learners' success. Providing multiple ways for learners to express their knowledge, demonstrate skills, and produce new knowledge helps both instructors and learners assess learners' understandings throughout the learning process.

Examples of how this emphasis could be applied in practice:

- Instructor supports a mix of participant structures within an activity, e.g., students could spend some time working independently, some time in groups, and some time learning from lecture.
- Instructor encourages students to express their new understandings in several ways, e.g., by talking about them, drawing figures, referring to graphs, and writing.

3.2. Learners' goals, interests, and values

Learners come into science and engineering lab experiences with different goals, interests, and values that are formed from their social, cultural and educational backgrounds, and are shaped by their future plans (see for example NRC 2007, and references within), and affect educational outcomes (for a review see Wigfield & Cambria 2010). They have different views of intelligence that can affect their goals and their motivation. In other words, their values and motivation are shaped not only by their own educational and career plans, but by their past experiences and backgrounds (see for example Osborne, Simon, & Collins 2003). Effective learning environments can be designed to anticipate and leverage learners' goals, interests, values, and provide motivation through activities that are relevant, meaningful, and challenging. Instructors play an important role in making curriculum equitable (e.g., Boaler 2002). They can find out about their learners' backgrounds, draw from them as resources, and help learners find connections and relevance to their own lives.

Examples of how this emphasis could be applied in practice:

- Activity goals connect the scientific content, processes, and attitudes students will learn or achieve to the learners' goals, interests, values, and potential motivations.
- Activity is designed so that learners can pursue the questions and/or investigation paths that interest them most.

- Instructor creates opportunities for learners to connect questions, problems, or investigation findings to their everyday lives

3.3. Beliefs about learning, achievement, and teaching

People hold different beliefs about learning, intelligence, achievement, and teaching that bring both learners and teachers into a lab with assumptions and expectations about themselves and the others in their learning environment (e.g., Bianchini & Solomon 2002). Negative stereotypes can be triggered by a range of aspects of the learning environment, can intensify learners' assumptions about themselves, and consequently can negatively impact learners' performances (see Steele & Aronson 1995; Gonzales, Blanton, & Williams 2002; as well as Stroessner & Good 2010 and references therein). If instructors do not convey positive and equitable views of learning, they can create environments that limit access and opportunity, particularly for learners of non-dominant backgrounds. It is therefore essential that instructors project high expectations along with support for all their learners' success. One way to do this is to approach intelligence as a malleable, rather than fixed, trait, expressing all students' ability to improve and build on their understandings (see Aronson, Fried, & Good 2002; Dweck 2006).

Examples of how this emphasis could be applied in practice:

- Activity is designed with multiple possible starting points, acknowledging learners' different prior knowledge and experiences, and reinforcing an expectation that they can make meaningful knowledge gains no matter what their starting point is.
- During student investigations in the lab, instructors give guidance when requested or needed but ultimately convey the expectation that learners will be able to "figure it out."

3.4. Inclusive collaboration and equitable participation

Learners' backgrounds can limit their access and opportunity to participate in science and engineering. However, their backgrounds can also be source of new ideas, new approaches, and new ways of applying results. Instructors can design and facilitate activities so that learners have equal opportunities to participate and equal access to resources in the learning environment. Collaborative participant structures are also important, as sharing and building upon others' ideas within collaborations is part of productive participation in science and engineering. Support and scaffolds for inclusive collaboration can therefore help all students participate in discourse, bring in their unique ideas, and solidify new understandings. Research supporting this emphasis reaches back to the work of Vygotsky (1978), and the fundamental role of social interaction in learning. Research on "cooperative learning" has looked closer at productive social interactions, and more specifically at the role in improving interactions between people of different ethnic backgrounds (e.g., Sharan 1980; Slavin & Cooper 2002).

Examples of how this emphasis could be applied in practice:

- Instructor encourages learners to write down their questions about a topic or phenomenon, then displays all students' questions anonymously, so that each question is given equal weight and equally valued.

- Activity is designed so that learners spend a significant amount of time working on a challenging and meaningful problem in small groups of 2–3 students, so that each student can make a significant contribution to the group's progress.

3.5. Social identification within science and engineering culture

Learners have social identities, or beliefs about who they see themselves as, who they want to become, and what they want to become part of (e.g., Brickhouse, Lowery, & Schultz 2000). They also have beliefs and preferences about how others view them, and under stereotype threat can "disidentify" with academic performance (Osborne 1995). There is an interplay between learners' social identities and the existing culture in STEM, which has its own norms, practices and values, and which can affect students' participation in STEM (e.g., Reveles & Brown 2008; Carlone & Johnson 2007). The STEM culture is shaped by the backgrounds of those historically dominant in the field, and may therefore make STEM less attractive to people from non-dominant backgrounds, and even drive some students out of STEM (e.g., Seymour & Hewitt 1997; Brickhouse & Potter 2001). On the other hand, social identification with the STEM classroom, or larger STEM culture, can lead to a sense of belonging. Attention to the interplay between students' cultural backgrounds and that of the STEM classroom, or the STEM culture, can help instructors create a more inclusive environment. Providing role models that students identify with can help, but effective mentoring can be, and should be, done by people of all backgrounds. Being explicit about the norms and practices of STEM while valuing students' own cultural norms and practices can help students of diverse backgrounds successfully navigate between STEM and their everyday lives.

Examples of how this emphasis could be applied in practice:

- Activity goals include learning STEM norms and practices, such as explaining or even defending one's results by referring to relevant data and scientific principles.

- Activity can be designed to include segments in which students describe their work informally, as they might to family and friends, and then describe their work formally, as they would at a conference.

- Instructor wraps up activity by reviewing learning goals and referencing each student's progress to reinforce their sense of accomplishment and belonging in STEM.

Summary of the Diversity & Equity Focus Area

Like the entire PDP, the Diversity & Equity Focus Area, and the five emphases above will evolve over time. There is still much to be learned about diversity and equity issues, and the practices that support learners from diverse backgrounds. However, enough is known to begin making changes in educational practices now. Many of the strategies that have emerged from the body of knowledge are simply good teaching practices that all students will benefit from.

4. PDP Diversity and Equity Workshops

Originally, the PDP engaged participants in the design and teaching of inquiry laboratory activities, and subsequent reflection on teaching practice. It was believed that inquiry strategies "automatically" address diversity and equity issues because inquiry is connected to research-tested frameworks such as *How People Learn* (NRC 1999, 2005b). However, both the PDP staff and its participants were interested in a much more explicit discussion of diversity and equity. Since 2007, we have designed and implemented a number of workshops within this PDP focus, and we describe them below. Not all of these workshops are currently delivered in every cycle of the PDP. Different workshops address different (sometimes conflicting) goals, and each has significant strengths and weaknesses, but each workshop supports or has led us to further refine our articulation of the emphases within the Diversity & Equity Focus Area.

4.1. Setting the Context for Discussions on Diversity and Equity

Before PDP participants take part in any diversity/equity workshops, we ask them to read a simple handout that we have created, which summarizes some strategies for having productive discussions about culture, diversity, and equity. These strategies are adapted from Gutiérrez & Rogoff (2003) and Weissglass (1990). This handout gets participants thinking about constructive, productive listening and discourse practices that prevent common pitfalls such as over-generalizing or discounting others' experiences. This discussion context can then simply be referred to and workshops can immediately invest time on the issues themselves.

4.2. Intern Panel

The first series of PDP diversity and equity workshops began with a small panel of undergraduates selected to express exactly the complex sorts of experiences that non-majority students have. At the time, many PDP participants taught in programs that attract, educate, and retain diverse students in engineering technology in the state of Hawai'i. (These programs have since evolved into the Akamai Workforce Initiative; see Hunter et al., Montgomery et al., Rice et al., Seagroves & Hunter, all in this volume). From the pool of past undergraduate Akamai interns, we approached a young woman and young man, both with Native Hawaiian backgrounds, to see if they would be interested in sharing their perspectives with future educators (PDP participants). We gave the panelists broad outlines of the types of issues we were interested in, namely, the ways in which cultures can both complement and conflict with each other, and the ways that students navigate the many cultures that they participate in. Within this general outline, we then collaborated with the panelists to develop what stories they might want to tell and what to expect from our PDP audience.

The panelists told stories of how they experienced conflict and tension: for instance, one intern was interested and engaged with the engineering work she was doing on Haleakalā, but was also aware that her presence there was not considered appropriate in a strict Native Hawaiian sense. Her story included how to feel that she was "being Hawaiian" while also "being" the other things she was interested in (e.g., an engineer).

The panelists also told stories of how they experienced resonance: for instance, one intern worked at what he felt was the modern analogue of an ancient Hawaiian lookout near his home. A common thread among all the stories was that culture is not static; cultures change and adapt, and members who identify with cultures must change and adapt to navigate them. *All* cultures and their members — including "cultures" such as STEM — must be open to such change and adaptation.

The power of this workshop is its simple direct access to the individual, personal experiences of real undergraduates. No discussion of demographics or of studies and findings sufficiently reminds participants that our students are *individual people* not easily summarized by their demographic data. On the other hand, this workshop has many shortcomings, both in principle and in practice. It is difficult to draw any general conclusions or lessons for the PDP participants, given the intrinsically anecdotal nature of the panelists' stories. We were tense about the danger that we might be tokenizing the panelists (or even that it might just appear that way). To address this tension, we made sure to collaborate significantly with the panelists themselves in the design of the session; in practice this makes planning the session relatively resource-intensive.

4.3. "Things We've Heard About Science and Engineering"

Some participants come into the PDP with strong or relatively rigid ideas about diversity and equity issues and may not appreciate that their peers hold different ideas or are not yet familiar with the issues. We designed a small-group discussion-based workshop called "Things We've Heard About Science and Engineering" that allows participants to discuss some of these ideas without (necessarily) personally claiming them.

We gathered a set of "things we've heard" which is shown in Table 1. These are real statements or ideas that we have actually heard (or read) expressed in the science/engineering communities. We selected them to represent some ideas that we agree with, some ideas that we disagree with, some that are well-intentioned but misguided, and some that are deliberately provocative and promote discussion. The workshop begins by handing out this table and letting participants read each statement and reflect on their own position with respect to that statement.

In small tables of 6–7 participants (plus a facilitator), what follows is a discussion of one of the "things we've heard." Each table is assigned a different statement to discuss, but the facilitator can choose to let the discussion range to the other "things we've heard" as s/he sees fit. Participants are asked to share what they think about the statement, whether it has or has not been their experience, why someone might have said it, and what arguments they may have heard for or against the statement. The purpose of the discussion is not necessarily to come to specific conclusions or draw "right" and "wrong" answers, but rather for participants to confront and reflect on their own preconceptions and those of others. For instance, the notion that "science is a meritocracy" can be assumed and taken for granted by many because it represents an ideal that science ought to aspire to; this does not mean that "science is a meritocracy" is currently, universally, unambiguously true.

As the PDP has grown, it has become difficult to adequately staff discussions with small groups such as this one. (In the current PDP we would need ~10 facilitators to implement this workshop.) While in other PDP workshops we draw on experienced, past participants to assist us with facilitating large numbers of newer participants, in the case of sensitive discussions around gender, race, and ethnicity we have found that these "helpers" are tense and feel unprepared to facilitate. This workshop has no lecture

Table 1. "Things We've Heard About Science and Engineering."

Science is a meritocracy (people advance and have opportunities based on their ability and work, rather than, for example, wealth, class, or gender).
Things have changed in science & engineering: women and minorities are well represented among young researchers, so in time they will advance, and be fully represented on STEM faculties.
Women need to become more like men to make it in STEM.
Underrepresentation of women in STEM is due to differences in innate abilities.
Science is Euro-centric — it emerged from a Western European cultural tradition so it's only natural that other constituencies participate less.
The main reason that women and minorities are underrepresented in STEM is because they don't have the preparation when they enter college.
Scientific research is often influenced by the experiences, interests, and values of scientists.
Culture and politics shape (and are shaped by) science.
There is not much a white male scientist can do in terms of mentoring and being a role model for women and minorities; women and minorities need to be the role models.
Relative lack of women in physics is because of the far greater number of gifted males, and the propensity of gifted females to choose other fields.
The way that we teach STEM affects who is in STEM.

or presentation component and is focused entirely on participants' reflection and small group discussions. Over the years we have developed several other workshops that are more passive and lecture-based, sacrificing time for participants to reflect and discuss. A change in PDP format so that the overall audience at any given time is not so large (so that they can be divided into these small groups without needing too many staff facilitators) would allow us to bring back this workshop.

4.4. Demographics, and Why We Care

While reflection, personal experience, and contact with the personal experiences of others are undeniably important, we also feel that participants need to see the demographics of STEM's diversity issues, and be reminded of broad motivations for addressing these issues. We developed a lecture-based workshop where we present data on the demographics of the U.S. college population, the recruitment rates into STEM, and the differing retention outcomes in STEM. We draw on reports such as Hurtado et al. (2010); National Science Board (2010); NSF (2006) to present these facts: Roughly representative proportions of students are interested in STEM degrees upon entering college, but some groups are significantly underrepresented in the attainment of those degrees. In addition, this situation varies by discipline, degree level, and specific underrepresented group under discussion, with some STEM fields achieving gender representation but not racial/ethnic representation, or some fields achieving proportional representation at the undergraduate level but being "stuck" in an underrepresented pattern for advanced degrees.

We interweave these data with arguments from Tilghman (2003) so that participants see the demographics of the problem and the motivations for addressing these issues side-by-side. For instance, in an adaptation of one of Tilghman's points, we point out that if some disciplines of STEM achieve proportional representation while others do not, it makes the latter disciplines look increasingly anachronistic and can further worsen the situation in the "lagging" fields by making them unattractive to talent from any and all groups.

This workshop is difficult to design because PDP participants have a broad range of prior knowledge of these demographic issues. Some PDP participants would be qualified to give the presentation (indeed one year we used data from the Nelson Diversity Surveys (Nelson & Brammer 2007) with one of her past research assistants in the audience) while other PDP participants are struggling with concepts that are new to them such as the distinction between a "minority" and an "underrepresented minority." We often get varied feedback on this workshop of the forms "I already knew this stuff, I wanted more on what I could do" along with "great presentation, I had no idea!" Overall, however, this workshop has been successful and had a positive enough impact on participants that we have implemented it for several years.

4.5. Case Studies in STEM Diversity & Equity

In response to participants' requests for more discussion directly related to their teaching, we designed a workshop where participants in small table groups (~8 per table, plus facilitator) read and discuss a "case study" which illustrates an interaction between undergraduates and their teachers. We borrowed scenarios from Sellers et al. (2006) and also developed scenarios of our own (see Appendix A); these scenarios were purposefully designed to have many interpretations. For example, a particular scenario might convey a teacher's instruction to a student, and this instruction might seem both well-intentioned from the teacher's perspective and discouraging from the student's perspective.

These scenarios give participants opportunities to discuss assumptions that might be made by teachers about students, by students about teachers, by students about themselves as learners, and so on. They promote discussion about how learning environments and curricula are designed, how teachers approach and interact with learners in the moment, and how these well planned or in-the-moment approaches can convey assumptions that affect students' learning. The Case Studies workshop sets up fertile ground for discussion, but sometimes does not lead participants to widely-applicable "lessons learned" as it can be difficult to generalize away from the anecdotal particulars of the scenario.

4.6. Identity, Stereotype Threat, and Growth Mindset

We developed a workshop that dives deeper into research and practices related to emphases 3 and 5 of our PDP Diversity & Equity Focus Area: beliefs about learning & achievement, and social identification within STEM culture. Within those emphases, we have chosen to focus specifically on stereotype threat, mindset, the interactions between these concepts, and effective strategies that educators can employ that come from this research. These issues directly relate to learners' beliefs about themselves, their beliefs about what others might think of them, educators' beliefs about learners, and the effects that society's stereotypes can have on learners even if no one in the learning environment holds those stereotypes. This workshop also provides us with an opportunity to discuss issues that specifically pertain to gender, race, and ethnicity, without (necessarily) the complicating socio-economic issues of class as well.

In preparation for the workshop, we have participants read some introductory articles. Then we begin by presenting an overview of stereotype threat, the "risk of confirming, as self-characteristic, a negative stereotype of one's group" (Steele & Aronson 1995). We present a summary of many of the basic findings of the stereotype threat literature; this summary is modeled after Stroessner & Good (2010). We broadly cover the consequences for learners who suffer stereotype threat: decreased performance, self-handicapping, disengagement, and disidentification. An individual in a stereotype threat situation (the "stereotypical" example of which is a woman in a mathematics class) under-performs relative to an un-threatening situation, self-handicaps by studying less or not trying as hard, and ultimately may identify less with the threatening domain and/or the stereotyped group. Perversely, those who identify most with stereotyped domains, for example women intending to pursue STEM graduate studies, are most susceptible to stereotype threat.

The literature (again, well-summarized at Stroessner & Good 2010) suggests strategies that PDP participants can employ that combat stereotype threat, including: cooperative learning structures (inherent to inquiry), high standards with quality instruction to help students meet them, and an emphasis on a "growth mindset" or view that intelligence is growable rather than fixed.

This leads to the next part of the workshop. We present the basic idea of "fixed mindsets" as opposed to "growth mindsets" and how a growth mindset can lead to more motivation, more effort, and ultimately increased performance (see seminal "mindset" research by Dweck). Encouraging learners to think of their intelligence as "growable" can lead to them welcoming challenges, being resilient in the face of failure, working hard, and can mitigate the effects of stereotype threat (Aronson et al. 2002).

Next we ask participants to discuss in table-sized groups how they could encourage (explicitly or implicitly) a growth mindset within the context of STEM laboratory activities (rather than through an external intervention like a separate discussion). Participants often realize that we may unconsciously promote a fixed mindset with the language that we use, such as when we reward quick correct answers over productive effort. Participants often decide to explicitly prepare their learners for difficult, frustrating, but ultimately rewarding efforts within their laboratory activities.

This workshop has worked well as the PDP audience has grown because it is relatively easy to implement — it is lecture-heavy and the small-group discussions do not require extensive facilitation. However, by having so much lecture and presentation, we sacrifice participants' active engagement in PDP workshops, so we make every effort to balance this with other, more active components.

4.7. Links Between Diversity & Equity Emphases and Inquiry Structure

One of the most recent workshops we have designed requires participants to grapple with the five PDP Diversity & Equity emphases and discern how they are modeled in an example inquiry activity. The goal is for participants to see strategies for addressing diversity and equity within the design of innovative, high-quality STEM laboratory activities, rather than as an extra burden to be placed atop or alongside these activities.

As part of their overall PDP experience, participants spend a great deal of time as learners in a "model" PDP inquiry activity, "Light and Shadow" (see Hunter et al., this volume, for more). In this workshop, we ask participants to highlight examples of the PDP Diversity & Equity emphases (§3.1–3.5) within the design of the "Light and Shadow" inquiry activity. Participants start in small groups, with each group assigned one of the emphases. They first discuss their emphasis to make sure they come to consensus about how they interpret it. Although we assign a description of PDP emphases as prerequisite reading, this is the first chance that participants have to discuss with their peers what the Diversity & Equity emphases mean. Once a small group has come to agreement about their emphasis, they review the design and structure of the "Light and Shadow" activity and highlight 1–3 strategies from the activity that particularly address their emphasis.

Next these small groups are "jigsawed" into larger groups. Within each large group, one or two representatives from each emphasis are present. In this way, the entire "Light and Shadow" model inquiry activity can be analyzed along the dimensions of all five Diversity & Equity emphases. Participants see that the design of an inquiry activity is layered: a component of an activity may serve an important STEM content goal, while also addressing learner-centered and community-centered needs. While this layering seems complex and difficult, participants also see that the PDP workshops have provided them with a rich model from which to work.

As an illustration: During the small-group investigation phase of the "Light and Shadow" model inquiry activity, small groups (2–3 learners) pursue a question they are interested in, and they are free to choose their investigation methods. Clearly the learners' goals, interests, and values (emphasis #2) are respected here. Furthermore, during this phase, instructors facilitate and guide learners but explicitly project an expectation attitude that learners can "figure it out" — thus sending important messages about the teacher's beliefs about learning and achievement (emphasis #3).

5. Challenges in Integrating Diversity and Equity into the PDP

The explicit integration of diversity and equity issues into the PDP has been a much-needed but challenging endeavor. A range of issues has come up, especially since our workshops are packed with other intellectually demanding, complex material, as well. There are two particular areas that require continual attention and balancing within this Focus Area: 1) valuing *both* personal experience and data; and 2) balancing background on diversity and equity with practical tools.

PDP staff have strived to develop a set of sessions that values and respects personal experience, while at the same time ensuring that participants learn about trends from national data sets and other data that illuminate important issues related to diversity and equity. Gender, race, and ethnicity (which form the "diversity" focus of PDP sessions) are sensitive topics and touch everybody in some way. Personal experiences provide potent examples for participants to draw on, either by considering their own personal experiences or those of others. However, limiting sessions to personal experience can give a very narrow view. One woman's experience in engineering could be very different than another's, and very different from the average experience nationally. Also, discussions of "my experience" versus "your experience" can be highly charged, and to be productive need to be carried out in a safe space and carefully facilitated discussion, which takes time and trained facilitators. Data sets (such as demographics of people in STEM in the U.S.) can highlight trends that might not otherwise be noticed, and give validity to experiences that might otherwise be discounted. On the other hand, statistics and large data sets have significant limitations. The details of why or how are missing, and the richness that is provided in personal accounts is lacking. Within the PDP, we have sought a balance, making sure that time is allotted to personal experiences (e.g. the Intern Panel described in §4.2, the "Things We've Heard about Science and Engineering" in §4.3, and the Case Studies in §4.5) as well as learning about what national data reveal (the Demographics and Why We Should Care session described in §4.4). Through multiple revisions, we have learned that the two perspectives are complementary, and need to be thoughtfully balanced.

The second major challenge has been finding the balance between providing background on diversity and equity issues, and providing participants with the opportunity to gain an understanding of the practical ways that they, as individual educators, can inclusively teach, and therefore have a positive impact on (or reduce the severity of) these issues. Participants want the knowledge, tools, and strategies to take action in the classes they teach, and with the students they mentor. However, using teaching tools and strategies without understanding why or how the strategies work is of limited use. Teaching and learning is context-specific, requiring constant adaptation of strategies to fit the particular needs of each situation, and instructors who are using teaching tools without understanding them are unlikely to be able to adapt them to their particular need. It is also unlikely that instructors will be very committed to using tools that they do not understand. Thus participants need to understand the theory and research supporting the tools. Furthermore, to understand the theory behind the tools, participants need to understand the issue the tool is addressing to begin with. And finally, they need to understand and care about the issue. Weaving all of this into a short workshop is very difficult, and making the tradeoffs almost never feels quite right. We always wish for more time, and at many points in the workshop development have even questioned whether it would be more appropriate to elevate this workshop to the level of a separate series of workshops, taking place over a day or two. At the same time, we believe that diversity and equity should be integrated into any training on effective teaching, and should not be considered a topic that is set aside and covered separately. The challenge of balancing background versus tools is an ongoing point of tension. Participants demand concrete tools, and we are still making revisions to the PDP Diversity & Equity workshops to make sure that participants come away with the tools to implement effective strategies.

6. Continuing PDP Diversity and Equity Efforts

The integration of workshops explicitly covering issues related to diversity and equity has been an enormously rewarding endeavor for the PDP community. PDP staff have debated, struggled, and learned — we have found this work to be some of our most innovative. PDP participants have embraced this work, also grappling with tough issues and learning, and they have been willing to engage in piloting new sessions and giving us honest feedback. Across the community we have simultaneously felt tension and the gratification of having a place to talk about issues that affect us all, often at a very personal level. The diversity and equity work of the PDP continues to evolve and new projects are emerging.

Over the years the PDP staff team has recognized the need for participants to examine their own beliefs about diversity and equity. This happens to some extent in our existing workshops, but it is probably insufficient. We have had to cut off discussions that participants clearly wanted to have (due to time constraints) and we have heard participant comments indicating that some unexplored beliefs were likely barriers to engaging in the workshop sessions, and thus barriers to changing practice. Others have also recognized this need and the potential obstacles that exist in implementing educational innovations with beliefs and perceptions left unexamined (e.g., Bianchini & Solomon 2002). Although we have identified this need, we believe that it requires additional workshop time, and carefully trained facilitators. Time will need to be spent creating a safe space, and learning about how to talk about diversity and equity issues with respect and sensitivity. In the future we hope to secure the resources for further workshop development and implementation, and a way to carve out additional time within the PDP.

New work has been initiated to use the Diversity & Equity emphases for workshops on mentoring. We have begun developing scenarios that can be analyzed with the emphases, as a mechanism for training mentors in effective mentoring techniques. We piloted the first scenarios within the PDP community, which were focused on a situation in which a student divulges to an instructor, "I think I've learned that I am not supposed to be an engineer." Variations on this scenario included what the instructor was able to learn from the student after further discussion. For example, in one variation the student indicated that s/he wasn't feeling successful in working on a team; another indicated s/he wasn't comfortable "arguing." Small groups of 2–3 participants were assigned to view the scenario through one of the five emphases and identify ways to handle the situation, or ways in which it might have been prevented from happening to begin with. The piloting was very successful, and in the future, we will build more scenarios to analyze in terms of how projects are designed, on-the-fly mentor moves, and the overall learning environment.

The PDP has continued through the Akamai Workforce Initiative (AWI) in Hawai‘i, which is bringing interesting new opportunities to expand our work. AWI is part of a partnership to develop a new engineering technology degree program at University of Hawai‘i, Maui College, which will include a strong focus on inquiry learning, and a curriculum that has cultural and community relevance. In addition, the program will be designed to retain students from all backgrounds, to produce a workforce that is more representative of the local population. The needs for the new degree program are an ideal match for the PDP, although the partnership requires expanding our work from the activity level to course- and program-level curriculum development. In our first phase we used the Diversity & Equity Focus Area emphases to review and then revise student learner outcomes (SLOs) for three new courses that are now moving through curriculum review. The emphases proved to be a very useful tool in moving from more commonplace SLOs to SLOs that explicitly addressed diversity and equity. We are now moving into the next phase and designing course components, and will provide training through the PDP to teach the new courses, or at least significant activities within the courses. This work has scaled up PDP work, and we hope that it will establish a model and tools for the broader STEM community to use.

Our work on diversity and equity has been an expansive and transformative experience for the entire PDP community. We hope that through this paper we provide insights, as well as some more concrete tools, that others can use. There is much work to be done to make science and engineering education effective and inclusive. We hope that we have inspired new work, in addition to advancing hundreds of early-career scientists into their careers with an understanding of the issues around diversity and equity, and research-based teaching strategies to teach more inclusively.

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Appendix A. Case Studies for the ISEE/CfAO PDP Diversity & Equity Workshops

These handouts are original case studies written by the PDP staff (copyrighted and reproduced here with the kind permission of ISEE/CfAO), for facilitated discussion workshops. See 4.5 for a brief discussion.

A1. Organic Chemistry (Case Study)

Professor Davis was proud of his efforts to be an excellent teacher, and was happy to see his students succeed. He worked hard to organize the material as clearly as possible and deliver excellent lectures. He wrote out detailed solutions to the assigned problem sets that displayed his thinking process as well as his obvious love for the discipline. And at a time when others in the Department had let lecture and lab sections grow apart, he made a point of teaching the lab himself. This semester he was excited to try something new — structuring the labs around complex, multi-week-long synthesis projects.

On the first day of class, he enjoyed giving an overview. “I know that Organic Chemistry has a reputation as a ‘weed out’ class. It was so at my University as well. It is true that there is a lot of material to learn — functional groups, reactions, and so on. But in my class, if you can think about the mechanisms involved, then you will be able to predict how molecules react. You will not need to memorize all the reactions.”

He couldn’t help but smile to himself as he got to this part. Although he was usually careful not to boast, he had recently compiled statistics for his tenure-review file and he knew: More than his fair share of students had gone on to the most prestigious MD-PhD programs in the nation. He finished his overview of the course, “Those of you who receive an A in my class are welcome to ask me for a letter of recommendation. I believe that success in this course is a good indicator of success in graduate school.”

“Now, without further delay. . . what I am passing around is 10 synthesis projects. I realize you do not yet know the chemistry behind these projects but I have written a short description that should give you enough background to interest you. I believe each project will take approximately 6 weeks to complete, but that depends on how you schedule your time. You will need to form groups and choose a project by the end of this week. . . ”

. . . AT THE SAME TIME. . .

As he’d entered Prof. Davis’s class, DeMarcus was excited and anxious about being at the University. *If I can do this,* he thought, *then maybe I’ll go to med school. . . or maybe I want to do drug research. Anything to help people.* A couple of years back he’d enrolled at the community college with no particular ambitions, but his mother’s illness that year focused his drive. He’d worked hard in the science and math sequences, catching up on his pre-reqs, earning a respectable B+ average, and gaining transfer admission to the University. DeMarcus knew OChem had a reputation, but he figured he was motivated to out-work, out-memorize, and out-compete any other student there. However, Davis’s emphasis on group work and critical thinking skills made him nervous; this wasn’t what he’d expected. *I’ll have to see how this goes,* he thought, *maybe I should check out the policy and politics programs too. . .*

. . . TWO WEEKS LATER. . .

By the class-drop deadline — two weeks into the semester — Ashley was still on the waiting list for subsidized University day care. Paying for her son’s child care was expensive; she was pulling extra evening shifts at the library beyond her work-study assignment and was about to take out another student loan. *Good thing Drew can look after the baby in the evening while I work — I don’t know what we’d do if we were both in school,* she thought. She knew she’d taken on too much course load. Something had to give. She logged into the online registration system. She couldn’t continue as a chemistry major and hope to graduate on time if she didn't do OChem this semester. But her synthesis project group always wanted to meet in the evenings, and she had to work. *I really like chemistry but I can't fit in all this evening group work right now.* She checked the box beside Organic Chemistry and clicked "drop".

A2. Jennifer Ka'akua (Case Study)

Jennifer Ka'akua smiled to herself as she walked to class. It was an unusually warm January day. She was starting her last semester of college and had satisfied nearly all of her physics degree requirements. As a result, her course load would be fairly light this spring.

She was on her way to statistical mechanics, a class she did not need for graduation. Still, she was considering taking it because she had heard Professor Harper was a good teacher. Her advisor had also mentioned statistical mechanics would give her good background for some of the courses she would take in graduate school.

As she entered the Tech building where all the science and engineering classes were held, she was relieved to find the right classroom quickly. This building was very large and was being remodeled, so some of the classrooms had been renumbered during the year. As she opened the door, she nodded to her fellow physics majors: Pete, Jeremy, Brian, John. It would be another small class.

Professor Harper finished writing some general information on the board and turned around to greet the class. He looked at the students and hesitated when he saw Jennifer. "Oh," he said, "I think you may have the wrong classroom. This is statistical mechanics." He gestured to the board where the course title was written.

"Yes," said Jennifer. "That's what I'm here for." She frowned slightly as Professor Harper turned back to the board to start working a problem. She listened to his lecture and took careful notes, but was uncomfortable about the way he had singled her out.

The next week, Jennifer ran into Jeremy at the coffee shop on campus. "Why didn't you come back to stat mech?" he asked her. "I'm really enjoying the class."

"I didn't get a very good impression of Professor Harper," she said.

Jeremy looked puzzled. "Really? I think he's an excellent teacher."

"Well, I don't really need the course to graduate," Jennifer said, "so I thought I'd stick with an easy schedule, too."

"Oh, that makes sense," said Jeremy. "Well, I'll see you in electronics lab."

"Yeah, see you," said Jennifer. She turned back to her coffee.