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Applying PDP Lessons Learned About Inclusive Teaching and Assessment

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Abstract

Much of the ISEE Professional Development Program (PDP)'s long-term value arises from participants transferring teaching approaches they develop in the course of designing and facilitating a PDP inquiry activity to other contexts throughout their careers. PDP participants encounter frameworks such as the inquiry framework and the equity and inclusion focus areas, and are encouraged explicitly to become informed consumers of further scholarship on teaching and learning. Many participants resonate especially with the PDP's emphasis on equity and inclusion in STEM teaching, and meld lessons from the PDP with their lived experiences as well as other scholarship on equity-minded or culturally responsive educational practices. Our panel shares four perspectives on extending lessons from the PDP to new contexts: mentoring students and developing interactive lessons in molecular biology, designing astronomy activities from a culturally relevant and culturally responsive standpoint, incorporating inquiry activities into a large astronomy lecture course, and helping academic programs across a university adopt equity-minded practices for assessing learning outcomes.

Keywords: assessment, course design, culturally relevant, culturally responsive, equity & inclusion, STEM identity

1. Introduction

"Inclusive teaching" encompasses a broad range of practices that may (or may not) be feasible and appropriate in an equally broad range of learning environments. In the context of the Institute for Scientist & Engineer Educators (ISEE) and its Professional Development Program (PDP), striving to teach inclusively starts by recognizing that disciplines in science, technology, engineering, and mathematics (STEM) historically have not been, and still are not, inclusive. This is evidenced by the skewed demographics of who earns degrees and advances as professionals in STEM disciplines, and by various ways that cultural norms in STEM reflect aspects of White supremacy culture and other oppressive systems (e.g., Prescod-Weinstein 2020;

2021; Okun n.d.). Inclusive teaching as emphasized in the PDP deliberately addresses the learning experiences of students who identify in ways that STEM norms are hostile to, or at least fail to nurture. At the same time, the PDP packs multiple themes and an intricate experiential component — designing and teaching a STEM learning activity following ISEE’s inquiry structure — into a finite program experience. PDP participants simultaneously consider inquiry, inclusive teaching, and their own STEM training and expertise. It is therefore no surprise that PDP alums’ descriptions and examples of inclusive teaching are highly varied and overlap with a range of themes and practices. Alums’ subsequent career trajectories add further diversity to their perspectives on inclusive teaching.

Our panel of authors samples the breadth of PDP alums’ professional experiences and the settings in which they are applying what they learned at PDP. Rather than a tidy synthesis of inclusive teaching methods or of the PDP’s most influential lessons, we offer four distinct narratives. Two of us hold university positions that contribute to shaping academic programs: an Astronomy Department faculty member (Casey: Section 2) and a university Academic Assessment Director (McConnell: Section 3). We each share how we draw from multiple PDP themes in our respective efforts redesigning lecture courses and assessing students’ progress toward program- and institution-level learning outcomes. The next two authors explore the PDP’s focus area of STEM identity in our respective work as an education researcher and program manager (O’Donnell: Section 4) and a molecular biology researcher and mentor (Macho: Section 5). Christine O’Donnell examines the PDP’s approach to STEM identity in comparison to frameworks emphasizing students’ critical identities, and addresses arguments resisting pedagogical change. Jocelyn M. Macho shares how her practices as a research mentor and K–12 instructor are a response to her experiences as a first-generation college student belonging to an underrepresented minority group and incorporate her experience with PDP themes including STEM identity. We conclude briefly with further insight from the broader community of ISEE PDP alums (Section 6).

2. Putting the PDP into practice: Lessons from large undergraduate classrooms —Caitlin Casey

My goal as an educator is to evoke students’ natural curiosities using astrophysical concepts as tools. When I ask students to reflect on how to calculate the physical size of the moon using their hands as rudimentary tools, or to calculate the surface temperature of the Sun using a few rough guidelines, a common question I hear is, “which formula do I use?” I see students grasping at irrelevant formulae, noting an aversion to spending more mental energy than is necessary to frame the problem. Secondary education has engrained this knee-jerk response as a lifesaving device for students who struggle to be quantitatively literate, painting over the missed links, and the innate curiosity that might have led to the student deriving the formula for her/himself. The primary objective of all classes I teach — from lower division to graduate — is to diagnose student understanding in context, and work to rebuild fundamental comprehension from the ground up using logic and intuition. My goal is to do this while building a thriving, equitable and collaborative learning environment.

My outlook on student learning has been shaped by my participation in the Institute for Science and Engineer Educators (ISEE) Professional Development Program (PDP). I first participated in the PDP while I was a postdoctoral scholar at the University of Hawai’i in 2013, then again as an Assistant Professor at the University of Texas at Austin in 2016. I did not know what to expect when I first entered the ISEE community, but what I took away was an experience that changed my outlook on both teaching and, more broadly, student learning, the student experience, and my own learning and research. As a

PDP participant and learner, I was astonished how my conceptual understanding of basic physics could grow an order of magnitude deeper by engaging with “simple” problems. Inquiry based learning facilitates that deeper understanding, and I knew it was an experience I desperately wanted to share once I entered the classroom as an educator.

Flipping the script on plug and chug was thus centered in my pedagogical philosophy as I began my faculty position seven years ago, in late 2015. I walked into my first classroom — an introductory astronomy class for science majors — prepared to make nearly all classes focused on inquiry-based learning. While my students’ resistance to this way of learning was palpable, I discovered that my optimism on their ability to engage with material deeply waned as reality set in on how *much* material I had to get through in a semester. How could I ask students to spend three class periods measuring the distances to star clusters, if they failed to fully grasp the building blocks of stellar evolution? Or could we forgo all discussion of gravitational waves and black hole mergers to make sure we had the time to fully explore age-dating stellar populations through inquiry?

The reality of the constraints of the classroom set in: I had a certain number of class periods to deliver a certain amount of material through lessons, and I needed to assess student performance and understanding along the way, sufficient to give them a letter grade by the end of the semester. My classrooms have had an extra challenge by sampling students at very different levels of preparedness for the material, some having mastered calculus while others struggled with basic algebra[1]. While I found I had substantial leeway in defining the course objectives and material, I knew my class was an essential building block for upper division material, and my program was relying on me bringing students up to speed on a huge range of topics. I had to make some difficult decisions on what material could be covered, and which material deserved more in-depth inquiry dives.

It was while I faced these challenges in my first semester of teaching that I returned to the ISEE PDP as a Design Team Leader in 2016; my team focused on an inquiry-based activity designed for summer research students in the TAURUS program. While my team and I had similar aims as other teams, to build an activity that facilitated students to discover their own path to a deep conceptual understanding of material, I approached the experience through the lens of an instructor facing very real practical constraints on student assessment and learning outcomes, in the broader context of my students’ long-term career goals.

Blending inquiry-based activities into a traditional lecture classroom is now the basis for my approach, particularly when faced with this challenge of meeting program-level learning outcomes at the curriculum level while still training students to engage with material at a deeper and more creative level. I aim to include five in-depth inquiry activities over the course of a ~25–30 course-long semester, and break up ~5–10 more activities into smaller pieces, scaffolded with probing questions throughout a few lectures. Having taught the same introductory astronomy class seven times to over 500 STEM students at UT Austin, I’ve noticed students’ initial reluctance to engage with open-ended hour-long activities is abated quickly when those activities are introduced early in the semester. Additionally engaging students with an open discussion of content and practice, and the importance of self-discovery within a STEM classroom, keeps motivation high while engaging with challenging material.

Several years later, I view my ISEE experience as a critical component of my understanding of what

[1] As the flagship university for the state of Texas, the University of Texas at Austin by law admits the top ~6% of every high school graduating class across the state, but this state — more than most — has a huge breadth in public school funding and performance metrics, leading to very different levels of preparedness for STEM material at UT.

learning *can* be, even if, in practice, it will not always have the freedom or time to reach as deeply as inquiry-based learning takes its learners. Both ISEE design activities taught me how thoughtful preparation centered on facilitation, minimizing clutter in course content, and a focus on learner background knowledge is critical to success in the classroom. All the while, backward design plays a critical role in working toward learning outcomes, both in the classroom and placing important constraints beyond the classroom, in the context of program-level curriculum goals and students' career goals. Mindfulness towards learners' communities plays a key part in the process, balancing traditional lecture with moments to pause and engage more deeply.

Recognizing what ISEE PDP gave me as a young scientist and educator, I have been eager to involve others from UT Austin in the ISEE PDP including UT-based graduate students, postdocs, and researchers so that they, too, are well-equipped to pursue teaching opportunities in the future. And beyond teaching, the PDP equips participants with an important awareness of learning goals that extends into research, public speaking, and connecting with others through mentorship. The UT Austin chapter participated in the ISEE PDP for a total of three years, sending a total of 15 participants (2016–2019), many of whom have engaged further with ISEE activities and/or brought critical lessons from the experience into other learning spaces, passing on these important lessons to a new generation of learners and scientists.

3. From inclusive teaching to equity-minded assessment —Nicholas McConnell

When I moved from an adjunct teaching position in Physics to a role directing assessment efforts across a three-campus university, I felt frighteningly underprepared. My introduction to assessment as a PDP participant, and later experiences assessing outcomes of PDP and other ISEE programs, were enough to get my foot in the door. And despite my doubts I've stayed afloat, owing a great deal to generous colleagues at my new institution and to communication and leadership practices I'd honed by witnessing and working with ISEE's masterful team. A year into my role, I still hesitate to describe myself as an "assessment person," yet I've learned and sometimes improvised enough to newly appreciate how themes from the PDP connect with program- and institution-level assessment. So far my work has been shaped by two invigorating challenges: promoting a culture of *assessment for learning* as opposed to compliance, and adapting assessment policies and practices to be more inclusive of diverse ways that students demonstrate learning.

3.1 Assessment for learning

At my institution and many others, assessment leaders are working to swing the pendulum from a compliance-based approach — wherein academic programs collect data mainly to appease external parties and prioritize external guidelines for what kinds of data are worth collecting — to a paradigm wherein programs define their own priorities for understanding their students' learning, are engaged in building meaning from data they collect, and use their findings to propose actions aimed at improving learning[2]. I sometimes refer to the latter as an inquiry-based approach to program-level assessment, a term I use loosely in acknowledging some

[2] Experts would point out that further assessment is necessary to determine whether follow-up actions were effective. In practice, where most faculty members and academic programs assess multiple learning outcomes and strain to meet numerous other demands, a reasonable goal is to make incremental progress toward this fully cyclical approach to assessment.

parallels to how inquiry is defined in the PDP. Pushing further in the direction of relationships and interactions between students and instructors is the concept of *assessment for learning* (e.g., Black et al. 2003; Wiliam 2011), which emphasizes how assessment can be a vehicle for real-time student learning.

The PDP's backward design approach (inspired by Wiggins & McTighe 1998) has strong connections to assessment for learning, as designing assessment is fully integrated with designing learning experiences — later PDP cycles even referred to the process as *assessment-driven design*. A core component of every PDP inquiry activity is the *culminating assessment task* (CAT), "an authentic assessment task that is part of the learning process and applies knowledge and skills to a real-world challenge" (Hunter et al. 2022). PDP design teams outline a CAT early and circle back multiple times to refine it as other parts of their activity are developed. This is meant to ensure that learning continues through the CAT and that evidence collected during the CAT speaks directly to the main learning goals of the activity. Inquiry activities end with a synthesis component that includes opportunities to give feedback on what learners demonstrated during the CAT.

Many academic programs I work with use an experience akin to a CAT as the basis of their assessment conversations: for instance, a senior research paper, capstone project, or PhD dissertation. Their instructors are poised to generate rich observations of learning and give students useful feedback as capstone-level projects develop. Yet when programs report assessment activities to the university, these same observations are too often sidelined in favor of reductive measures designed to standardize information across programs. In my role overseeing assessment reporting, I am challenged to develop processes and requirements that balance creating a university-wide portrait with conducting nuanced and responsive investigations of learning.

3.2 Equity-minded assessment

As issues of access and equity have received more urgent attention in U.S. higher education, assessment staff at universities have sought to adopt practices aligned with *equity-minded assessment* and related frameworks (e.g., Montenegro & Jankowski 2017; 2020; Dorimé-Williams 2018; Henning & Lundquist 2018). In this short piece I cannot do justice to all the dimensions of equity-minded assessment, but I will remark on some areas that resonate with my recent experiences. The first is tension between examining students' learning in a way that faculty and administrative stakeholders view as reliable — i.e. methodologically sound or even statistically "rigorous" — versus expanding how, when, and where students can provide evidence of learning, and deriving meaning from data that are less homogeneous.

On the one hand, carefully designed assessment procedures can help mitigate assessors' own biases, and statistical methods can help distinguish pervasive trends from tenuous examples. Yet overreliance on statistics can erase or dismiss entire groups of students, particularly groups that are underrepresented and hence deliver smaller sample sizes. Dismissing underrepresented students' experiences as (statistically) "insignificant" is especially common in spaces where quantitative data tend to be valued above narrative experience ("anecdotes"). A related premise is that assessing a standardized assignment or task provides more "objective" insight than offering a variety of ways for students to respond or leveraging students' self-assessment — and furthermore that this alleged objectivity is desired. Assessment for learning and equity-minded assessment both ask, do we serve students more by regarding them as objects of assessment ("data points"), or as subjects navigating their own learning?

I am still trying to catch up to my assessment colleagues in learning quantitative and qualitative tools to address evidence collected through different assessment measures. At the same time, I bring a strong PDP-inspired philosophy of creating assessment tasks and communicating assessment findings in ways that empower students — by supporting their agency as learners and by creating platforms for them to speak on their own behalf. The PDP guides participants in designing activities where learners have "multiple ways to productively participate" (Seagroves et al. 2022), especially ways that promote cognitive autonomy over superficial choice (e.g., Stefanou et al. 2004; Perez et al. 2022). In a STEM inquiry context, this might include formulating one's own research question or engineering requirement, specializing in a particular line of evidence, evaluating what kinds of evidence should be considered, and/or determining how to illustrate findings or communicate a concept. While PDP participants devote extensive effort channeling these relatively autonomous activities toward a single assessment task, educators who engage students over an entire semester or degree program have more flexibility in choosing — and in seeking students' input on — the best opportunities to evaluate and recognize learning. Part of my job is encouraging faculty to make use of this flexibility and to critically examine the rationale for longstanding assessment practices in their programs.

Another area where equity-minded assessment and the PDP approach align is in encouraging transparency in conveying learning goals and learners' progress toward them. Although designers are coached to avoid CAT prompts that overly constrain how learners should approach the task (i.e. a detailed list of instructions), they are encouraged to directly name the learning outcome the CAT is designed to address and even to share a version of the rubric with learners that indicates major elements of the learning outcome[3]. Furthermore, PDP inquiry activities include *contexting* at key moments: brief announcements or reflections that orient learners to the activity's structure, affirm how they may be feeling, and share the expectation that they will succeed even outside of their comfort zone. These and other strategies for transparency — such as sharing the purpose of assignments and how lessons and assignments relate to professional skills — have been shown to reduce gaps in achievement (e.g., Winkelmes et al. 2016), likely by unveiling parts of the "hidden curriculum" that consume precious bandwidth for students whose identities or experiences do not readily align with expectations set by the dominant culture. Individual instructors and whole academic programs can move even further in the direction of equity-minded assessment by enlisting students' input in defining learning outcomes and by co-creating assessment tasks with students.

My journey through inclusive teaching and assessment returns often to a design practice I first encountered in the PDP: envisioning the experiences of students — not just a "typical" student, but multiple students who have different strengths and different outlooks on the content being studied and the act of learning itself. Protocols that narrow what is acceptable for the sake of methodology or efficiency are suspect, and educators must weigh the demands of systems that are already in place against the needs of students whom those systems routinely exclude.

3.3 Coda

A practical lesson I've learned and re-learned since my first PDP experience is to prioritize a small number of learning outcomes or unanswered questions. This applies to designing a lecture, an exam, an inquiry activity, a research proposal, a program- or institution-level assessment plan, and more. Prioritizing is not the same as culling: a learning activity will still have fleeting pieces that intersect with various skills or attitudes, and students' growth toward a high-level learning outcome will incorporate

[3] PDP instructors frequently tried to counter a misconception that pushing students to develop their own knowledge during the inquiry process should include withholding the major learning outcomes of the activity. An inquiry activity's overall goals should be conveyed from the outset, rather than unveiled at the end.

many relevant and even some tangential competencies. But trying to cover all bases equally is overwhelming and usually counterproductive. Conserve energy by identifying central goals that can consistently inform the many decision points awaiting downstream.

4. A culturally relevant and responsive lens on the ISEE Equity & Inclusion theme —Christine O'Donnell

For me, one of the most unique aspects of the PDP was the emphasis on ISEE's Equity & Inclusion (E&I) Theme. Although there have been innumerable reports over the past many decades about the lack of diversity in science, technology, engineering, and mathematics (STEM), the PDP was the first time I encountered the explicit application of equity and inclusion to a college-level classroom. As cited in the ISEE E&I Theme, this approach is motivated by the fact that while students from marginalized gender and racial/ethnic groups enter college interested in STEM majors at a similar rate to White students, these individuals are much more likely to switch out of STEM majors or leave college (e.g., Hurtado et al., 2010; Riegle-Crumb et al., 2019). Both *Talking About Leaving* (Seymour & Hewitt, 1997) and the follow-up *Talking About Leaving Revisited* (Seymour & Hunter, 2019) found that classroom experiences were among the top reasons why students left STEM majors.

The ISEE E&I Theme was not the first effort to explicitly incorporate equity and inclusion into pedagogy. Two prominent frameworks are culturally relevant pedagogy (Ladson-Billings, 1995a, 1995b) and culturally responsive teaching (Gay, 2010). In my full proceedings paper, I re-examine the ISEE E&I Theme and compare its characteristics with culturally relevant and responsive education, with the goal of identifying directions that an instructor who is already familiar with the ISEE E&I Theme might pursue to make their approach to equitable and inclusive STEM education more robust.

Briefly, all three frameworks were designed to empower students to be active participants in teaching and learning. They each incorporated a growth mindset and validated students' cultural heritages and assets. However, there were also key differences, especially in their conceptions of students' identity development. The ISEE E&I Theme took a narrow approach, focusing on students' identities as persons in STEM. On the other hand, culturally relevant and responsive frameworks emphasized a critical identity: students grow their cultural pride in sync with their academic successes; prioritize community building and cooperation; and develop a critical consciousness that empowers them to address inequities in their communities.

One reason for these differences is that the frameworks were created for different settings. The ISEE E&I Theme was designed for the PDP, a limited series where early-career STEM professionals create a single inquiry activity for college-aged students. Both culturally relevant and responsive education were developed for the K–12 classroom, where teachers often have more extended contact with students over an entire academic year, though they are also valuable in the college classroom environment.

Finally, there are a variety of frameworks that incorporate both critical consciousness and STEM identity development, including techno-social change agents (Ashcraft & Eger, 2017), transformative intellectuals (Morales-Doyle, 2017), and critical science agency (Basu & Barton, 2009; Basu et al., 2009). In my own work, I have used these frameworks to create astronomy curricula for high school students (O'Donnell, 2021) and to create astronomy/geosciences citizen science-based activities for general-education college courses.

When sharing my work, I have encountered a few common themes in questions and comments, often in the context of suggesting that the frameworks somehow do not or should not apply in specific cases. Below, I offer responses to these themes.

4.1 (Advanced) STEM topics are not "culturally relevant"

Some of the comments that I have received on my work include that there are some topics in STEM that do not have cultural relevance. Often times, this comment is made in the context of advanced STEM content. For example, in quantum mechanics courses, students are given a variety of situations where they apply the Schrödinger equation to determine a particle's wave function. While the act of solving that equation may not have clear cultural connections, the field itself involves many aspects beyond only the math. To offer a brief list:

- There is historical context for what is considered "quantum mechanics" and who is recognized as being a part of the field. The "Schrödinger equation" honors Erwin Schrödinger, but when physicists use his name, they rarely discuss historical implications such as who was (and is) allowed and able to be a physicist, nor do they discuss who Schrödinger was as a person. His life story is much more complex than "he was a physicist", such as being one of the many people who had to flee Nazi Germany.
- The field's inherent values are reflected in how funding is allocated. Chanda Prescod-Weinstein (2020) wrote about this prioritization through the lens of "White empiricism". She described the dichotomy between how string theory — a field that currently has no empirical evidence to support it — is given large amounts of funding while the experiential evidence of Black women about harassment and exclusion is not given the same level of credence.
- The field has adopted specific norms and expectations (i.e., culture) for how members interact with each other, e.g., how to collaborate, how to publish and/or present research results, and how to award promotion and tenure.

These three examples are far from an exhaustive list demonstrating how *culture* is present in quantum mechanics, and similar arguments can be made for other STEM topics that may not be obviously "culturally relevant": while the content may not have obvious connections, the practices of the field certainly do. In college courses, especially advanced courses where topics like the Schrödinger equation are covered, one goal is often to prepare students to be the "next generation" of scientists. The ISEE Inquiry Theme makes a similar argument in its focus area on mirroring authentic research and design. By not discussing these connections, instructors are not truly preparing students to be members of the field.

4.2 Students in STEM college courses are from many different cultures

Another concern is how college courses can be a lot more diverse than a K–12 classroom. Although students in a K–12 classroom frequently come from a small geographic area, those students do not represent a monolithic culture, and they may come from many nationalities and cultural groups (e.g., schools that serve both local and refugee communities). That said, large college classes with hundreds of students can be much more complex. How can an instructor attend to all of the possible cultural backgrounds present in that kind of classroom?

My perspective is that the question requires reframing. Rather than expecting the instructor to attend to all of the cultures that are present, they should create spaces where the *students* can incorporate their cultures into course activities in a way that is validated and affirmed. Even in settings where students come from a narrower range of backgrounds, it may not be appropriate for the instructor themself to share stories from the cultures represented amongst their students. For example, some examples of cultural astronomy content include Indigenous stories, but if an instructor is not from that particular culture, they may not be able to share the stories in a respectful way, e.g., due to customs about who can share the stories or about when during the year certain stories can be told. However, that same instructor can work with members from a local Indigenous community to create respectful spaces for those stories to be incorporated. Furthermore, in large classrooms with many cultures, an instructor can still *model* that cultural knowledge is valued and recognized (e.g., by bringing in speakers from local communities), and then create spaces for students to offer their own knowledge and assets. These approaches also allow students to be recognized for their expertise as part of the course, which can contribute to their identity development as well.

4.3 Cultural beliefs are not "science"

A third category of comments is from people who wish to draw a distinction between cultural beliefs and "science". These comments often presume or imply a prioritization of what the commenter considers "science" above cultural values and beliefs, which is another version of White empiricism (Prescod-Weinstein, 2020). In an educational context, creating this type of distinction can prevent students from achieving long-lasting learning. Fink (2013) modeled students' mental processing as sorting information into a "course file" (the content that a student will use on homework, etc. but will likely purge at the end of a course) or a "life file" (the content that a student will use and retain for their day-to-day lives). Creating (or implying) a hierarchy that places science above the cultural beliefs that are already within students' life files will result in students mentally filing science content into their course files and thus not retaining it, limiting students to short-term learning gains.

While a more complete discussion of how to frame science and cultural beliefs is beyond the scope of this paper, one approach is through multiple ways of knowing and understanding. All of these (potentially conflicting) worldviews are because people have always been trying to understand the world around them. What we call "science" is just one story and way of understanding, and accepting that there are different stories and different ways of knowing can be an approach to recognize and affirm students' own beliefs (e.g., Barton, 1997).

4.4 There is a lot of work required for instructors

A final theme is that asking instructors to address both culture and typical STEM content is a lot of work and requires re-thinking many aspects of course design. While I encourage instructors to take an approach similar to the PDP's — critically reflect on your course, identify a single activity or a single course aspect, and start there — it still frequently entails a significant course redesign. I also believe that this level of effort should not be unexpected. To repeat the oft-quoted admonishment by Audre Lorde, "The master's tools will never dismantle the master's house" (Lorde, 2003). Transforming STEM to be equitable and inclusive means that we have to re-construct and co-construct the systems, cultures, and norms that make up STEM, and that is a lot of work. Finding a supportive community of practice is a step that can alleviate some of the burden.

4.5 Discussion and next steps

In summary, by re-examining the ISEE Equity & Inclusion (E&I) Theme in comparison with culturally relevant pedagogy (Ladson-Billings, 1995a, 1995b) and culturally responsive teaching (Gay, 2010), I identified possible directions that an instructor familiar with the ISEE E&I Theme might pursue to be more robust in their approach to equitable and inclusive education. The most significant of these directions was incorporating a critical identity into students' STEM identity development, which involves prioritizing cultural pride, community building, and critical consciousness.

Responses to advocating for these approaches can include concerns about whether STEM topics are really culturally relevant, whether it is possible for an instructor to attend to the needs of a diverse classroom, how those cultural beliefs can co-exist with "science", and how much effort is required from instructors. While transforming all of STEM education will take much work to re-construct and co-construct systems, cultures, and norms, these are possible and very-needed changes. Many of these concerns can be addressed by reframing the comments themselves. These frameworks offer an approach to be culturally relevant and responsive when it comes to STEM content *and* practice. Instructors can create spaces for students to offer their cultural knowledge and assets in a way where both students' assets and science are affirmed as ways of knowing and understanding. By embedding these principles into STEM education, we can guide students to develop critical STEM identities that will empower them in STEM and beyond.

5. Applying inclusive teaching in research-focused environments to increase STEM identities —Jocelyn M. Macho

I am a trained natural products chemist currently working as a postdoctoral fellow in a synthetic biology lab. I have persevered in science largely in part to the mentorship I have had throughout my schooling. As a minority, first-generation student, my family and community were unable to help navigate me through my career, so these programs were critical for my progress as they helped guide me on my pursuit of scientific research. Since I experienced firsthand the profound impact of such programs, I understand how crucial the right support systems are for success; thus, giving back through mentoring and building up underrepresented communities is a necessary component for my future career. I aim to do this through teaching, mentoring, and outreach in research-focused environments. I participated in the Institute of Science and Engineer Educators (ISEE)'s Professional Development Program (PDP), while as a graduate student, to develop both my teaching and mentoring skills and was able to enhance those skills by teaching through UC Santa Cruz's WEST and ACCESS programs (Santiago 2022). Being part of this community helped me reevaluate the small steps I could take within the lab to better foster learners' STEM identities.

During my graduate school career, I had the opportunity to train multiple different learners that came through our lab. As this was the first authentic research experience for most of these learners, I wanted to provide a positive experience that would properly train them for their future careers. Most importantly, I try to be very cognizant of developing STEM identities. *STEM identity* is the belief that one can perform the tasks that a scientist can — it is a level of self-esteem and confidence of one's abilities in their respective (STEM) field(s) (Singer 2020). Many first generation and learners from underrepresented backgrounds have low or limited STEM identities because of lack of appropriate and authentic STEM experiences, lack of support from meaningful others in their community, and lack of appropriate representation, (Hazari 2013). For example, I came from a poorer community with limited resources, and I remember in one undergraduate research position feeling so out of place because I was struggling with course material, and I didn't have the same experience as others at my level. I was looking to learn more about the field and level up my skills, but I was so ready to quit because I wasn't properly supported in that lab, and I was so frustrated with my lack of experiences. My lack of scientific background and my struggles in college-level chemistry courses were frequently questioned and mocked. I spent most of my first undergraduate lab experience working as a dishwasher instead of building meaningful skills or learning to think in broader terms. At another experience, later in my career, I was told I wouldn't make it in chemistry and needed to consider changing fields of study all together. All this slowly chipped away at my STEM identity, and I wouldn't have made it through the programs if it wasn't for my support systems helping me realize and reestablish the confidence in my abilities.

Because of these experiences, I want to instead be a productive mentor that helps instill STEM confidence in my learners with fruitful mentorship through training in authentic research experiences, which is so important because a strong STEM identity helps for retention in the field. Participating in PDP helped me learn key teaching techniques and helped me develop the facilitation skills to not only teach technical skills to learners, but also help foster their cognitive skills and STEM identities by allowing them to take ownership of their learning through authentic practices.

5.1 Action items that help increase STEM identity through authentic research practices

Our activities in PDP were designed in a way that allowed exploration of a topic through various routes and still reach the same learning objectives. In the lab, I follow this with my learners by allowing them to **choose which project** or **which aspect** of a larger project they'd like to focus on. While all learners will have a learning curve to overcome, and the same basic skills to learn, it is very important to have students choose which project(s) they want to work on to meet their learning objectives — developing their cognitive and technical skills, and developing the confidence in their STEM abilities. Students should be able to explore topics and skills sets that are of interest to them. In our natural products lab for example, we worked on chemical synthesis, microbiology, isolation, and molecular biology, and while there was some overlap, learners would gain experience in certain skills more than others depending on their project. Their ability to choose their focus decreases the level of intimidation, allowing for easier adjustments to new work and environments; allows them to feel like they are making a difference because they are contributing to projects that are important to them; and allows the learners to pull from their past experiences (or work towards future goals) if there is a connection. Additionally, being able to choose their focus doesn't deter from their ability to perform, rather it can help build up their skillset and confidence that will allow them to better tackle more challenging skills later in their tenure. For example, a student may struggle more in synthesis than in isolation (or find more appeal in isolation than synthesis), but one route can lead to another. In graduate school, for example, I had multiple isolation projects and one of my learners had a particular interest in developing synthetic skills. I suggested that she be mainly involved with my insect project, where she would mainly be devoted to functionalizing metabolites to study subsequent insecticidal activity, but would need to also need to learn isolation skills. She would really look forward to coming into the lab because she was able to gain firsthand experience with synthesis, which was her interest in career choice, and then really began to enjoy the analytical side of things, which originally intimidated her due to some of the more complex machinery involved.

While the learners are actively involved with a project, I am sure to have them **engage with the literature**. At first this is me sharing with them background literature on the project and working with them to learn to read and digest scientific papers. Then I slowly put more and more of the "finding literature," responsibility on them and have them interact with other papers related to our field (to expose them to our field overall, in efforts to help them discover their interests and find their niche). This not only builds their background knowledge and **communication skills**, but also helps them understand the project-planning process. I try to make sure that the learners understand why we are working on a project and why we make the experimental decisions that we do. This not only helps build their cognitive thought and reasoning skills, which is rarely ever formally taught in grade school and undergraduate curriculum but allows the student to translate what they are learning to different contexts. Along with this, students are encouraged to present at group meetings, write abstracts, and present posters at university symposia. Emphasizing student reflection not only helps them cement their learning, but it also works towards developing their confidence in scientific communication (Santiago, 2022); these are skills which students lack confidence in due to their relative absence in undergraduate curriculum.

Along with this, I actively try to **move away from writing to-do lists** for my students. As the learner engages and becomes more comfortable with the work, I try to find opportunities to **shift cognitive thought and experimental planning to the student**. This is like the PDP activities in which learners designed their own experiments to test a phenomenon during their two-day activities. For example, it is very common to perform chemical modification on a natural product or to synthesize specific metabolites, and reactions often require optimization to drive the desired product's yield. Optimization requires changing various factors such as reagents, temperature, solvent, and pressure, which can be a facile way to have learners engage in planning and conducting their own experiments. Or, when we are trying to isolate a novel metabolite from a complex organic mixture, it often requires optimization of a chromatographic series to yield a purified product. Allowing the student to propose and conduct purification methods is an excellent way to have the student apply their knowledge of NMR, LC-MS, and chromatography, which is the exact thought processes we go through, but instead gives the learner a sense of autonomy and helps develop their critical thinking skills.

Outside the lab, I'm using the PDP framework to develop interactive lesson modules to bring molecular biology and natural products to underrepresented communities who might not have access to these learning opportunities otherwise. These are designed as month-long modules for learners in K–12 to actively engage in inquiry activities that mirror authentic research activities, like those taught during PDP. These activities incorporate the same authentic STEM practices used in the research lab, allowing learners to explore core concepts at their own level(s) of comfort and understanding. Inquiry activities are designed with an intended learning outcome that uses a core concept to explain a phenomenon and raises "how" or "why" questions like data acquisition in a research lab. This will allow the students to engage in many STEM practices throughout their investigation, while synthesizing their observations with previous experiences to solve a problem. The students I want to target do not have the resources, including genetic tools, to learn molecular biology; thus, teaching through this program really would help break barriers for learning synthetic biology and genomics. These **active learning** activities likewise shift responsibilities to the students, that they may not have had otherwise, and are coupled with standard lab practices such as keeping a lab notebook, and wearing personal protective equipment, etc. to help build their confidence in their abilities as scientists, empowering them to pursue their goals.

In both avenues, the research and outreach labs, learners are provided with **targeted feedback** — that is feedback specific to the learner, rather than generic support statements (i.e., "you're doing great) — and both praise and critiques are constructive and framed positively to encourage growth. Additionally, learner-interaction is specific and invokes critical thinking, without giving away answers — challenging the students to think. This helps ensure that the learner feels heard and respected while also providing feedback with attainable goals that will keep them motivated. Additionally, both settings are designed as **safe learning environments**, where there aren't wrong answers or stupid questions. Rather **growth mindset** is emphasized, so mistakes are seen as learning opportunities and negative results can still provide insight to the phenomena at hand.

These are important discussions as it helps frame the thought processes involved with data analysis while also helping them build their reasoning skills. Likewise, this type of feedback teaches students to filter through their data and look at things from different angles as opposed to sinking to a feeling of, "I didn't get the right answer, thus I am a bad scientist," or similar feelings — sentiments of imposter syndrome — that are so easily felt amongst members of our community. And important to this, as facilitators, is owning up to our own mistakes, because our learners need **authentic role models**, who adequately reflect the field and aren't perfect, allowing the students to see themselves in their place. And that's the key take away from PDP, in my opinion — **authenticity**. We design our activities to mirror authentic research; we encourage our learners to embrace their strengths, acknowledge where they are, and ask the questions they need to regardless of how they compare to their peers, because science — like education — is a growth mindset, it's ever expanding, and we need to acknowledge what we don't know so that we can continue to learn. And as facilitators, it's a disservice to our learners if we do not admit our mistakes or shortcomings because if not, we create unrealistic images of scientists for our learners, making it easier for them to fall into disrupted STEM identities. So, all-in-all, we as educators need to establish environments where students can safely ask the questions they need to grow and be confident with their abilities, and we need to set realistic and attainable — authentic — expectations of scientists and research.

6. Concluding ideas and input from PDP alums

The PDP curriculum includes conceptual structures for inclusive teaching along with realistic examples that participants reflect on from the standpoint of learners as well as instructors. The curriculum has been developed such that inquiry, assessment-driven design, and equity and inclusion thread the entire program as intertwined themes, acknowledging direct as well as nuanced ways they overlap. Nonetheless, participants have opportunities to focus on a specific theme or narrower sub-theme at moments when it is especially relevant for a particular teaching context. The program's complexity and strong experiential component open numerous avenues for alums to advance their inclusive or equity-minded practices as educators.

The perspectives shared above articulate only four of the many possible outcomes for PDP alums. At the 2022 PDP reunion conference several alums added their perspectives and insights to the ones we have shared in the preceding sections. Additional aspects of the PDP that alums named as supporting their development as inclusive educators include:

- Deliberately cultivating an interdisciplinary PDP community, such that frameworks and vocabulary introduced in PDP gave alums an entry point to engage with discipline-based education research as well as general scholarship in teaching and learning.
- Demonstrating parallels between learning processes and processes of STEM research — such as use of prior knowledge, stepping beyond one's comfort zone before achieving a breakthrough in understanding, and co-constructing knowledge with peers.
- Use of a deep and extended design process, along with reflection, to develop intentional teaching practices that could later be deployed within the PDP's inquiry structure or in other settings that require different approaches.
- Resisting the idea of a perfect teaching activity, in favor of activity designs that can be re-assessed and improved multiple times or adjusted to meet the needs of different groups of learners.

The PDP has contributed to its alums' inclusive teaching and inclusive professional practices in numerous ways, and in a new context might still expand its scope to incorporate additional critical perspectives.

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