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The Value of Teaching Leadership Skills to STEM Graduate Students and Postdocs

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Abstract

To create and achieve awesome things in the world together, STEM (science, technology, engineering and mathematics) professionals need to be able to lead effectively. Leadership can be thought of as "a process of social influence through which an individual enlists and mobilizes the aid of others in the attainment of a collective goal" (Chemers, 2001). In the Institute for Scientist & Engineers Educators' Professional Development Program (PDP), STEM graduate students and postdocs learned, practiced, and reflected on leadership skills and strategies explicitly. Design Team Leaders (DTLs) practiced leading their teams, all participants facilitated inquiry (led their students in learning), and some (in later years) learned through the inclusive leadership PDP strand. In this panel paper, we reflect on what we learned from these experiences and discuss how we apply PDP leadership training daily in our work beyond the PDP. We review key principles about inclusive leadership, such as building an image as a credible leader; how to lead meetings; and how to build feelings of motivation, belonging, trust, and shared ownership among team members. We also share case studies of our experiences applying PDP leadership training in roles as co-director for an African summer school, facilitator for a physics equity project, middle/high school math and science teacher, mentor for new teachers, teaching professor and online curriculum designer, and project manager for a non-profit. Last, we offer recommendations for stakeholders who want to support STEM graduate students' and postdocs' development as inclusive leaders.

Keywords: equity & inclusion, leadership, professional development

1. Introduction

Effective professionals in STEM (science, technology, engineering and mathematics) need strong inclusive leadership skills. Working in a team allows people to create and contribute much more to the world than alone — and requires one (or more) person to act as an effective leader, using "social influence ... [to] enlist and mobilize the aid of others in the attainment of a collective goal" (Chemers, 2001). Furthermore, Shore et al. (2011) advocate

for inclusive collaborations in which each person "perceives that [they are] an esteemed member of the work group through experiencing treatment that satisfies [their] needs for belongingness and uniqueness." These ideas together form the basis for the concept of "inclusive leadership." Many scholars have developed this concept further, in particular centering the importance of equity and justice in leadership. Due to limited scope for this writing, we mention only these two articles, because of their focus in the PDP (described below).

It is highly valuable to provide training in inclusive leadership to STEM graduate students and postdoctoral researchers. These emerging STEM professionals, who may work in or outside academia in their future, can develop their skills through instruction that draws from the wealth of research on leadership and inclusivity, practice, feedback, and reflection. This article focuses on the Professional Development Program (PDP; see Hunter et al., 2010 and Hunter et al., 2022) from the Institute for Scientist & Engineer Educators at the University of California, Santa Cruz, which taught inclusive leadership through several avenues, all related to designing and teaching an inquiry-based educational activity in STEM. All PDP participants learned inclusive leadership of students; Design Team Leaders (DTLs) learned further through the experience of leading their PDP teams; DTLs in the Inclusive Leadership strand learned through explicit scaffolding, coaching and reflection on inclusive leadership; and others learned through working on PDP special projects and serving as PDP Instructors and Apprentice Instructors.

The PDP emphasized a three-element framework of leadership from Chemers (2001): (1) Image management: establishing and maintaining an outward image as a credible leader; (2) Relationship development: motivating team members to give their best; and (3) Resource deployment: drawing the team's energy and knowledge to move the team towards their collective goal.

We are four STEM professionals who participated in the PDP (2009–2021). We each learned about inclusive leadership and now find these skills valuable in our careers. Four principles of leadership — that have overlap with those in Chemers (2001) — are particularly important to us in our work across our very different contexts. The second and third also connect with Shore et al.'s (2011) above description of inclusion.

1. *Holding a growth mindset towards leadership.* Viewing leadership as a skill that we each can continue to intentionally learn and develop.

2. *Facilitating effective and inclusive meetings and classes.* Leading meetings and classes that move team members and students towards agreed-on goals, in a way that values everyone's contributions. This includes recognizing and working to mitigate systems of social power inside and outside the team. This principle connects to Chemers' third element of resource deployment, and comprises both practical and relational aspects.

3. *Building shared ownership and sense of belonging.* Helping all team members to feel that they have agency in shaping the project, and feel valued and belonging within the team, all of which support members' motivation. This connects to Chemers' second element of relationship development.

4. *Building a credible leadership image.* Chemers (2001) defined this as the first element of effective leadership, and it can be achieved through presenting expertise, transparency, and reliability.

Below we share four case studies, each written by a member of our panel, about our individual experiences with leadership in the PDP and subsequent careers.

2. Leadership as co-director of a summer school and facilitator for an equity project
—Linda Strubbe

I am grateful to the PDP for giving me a strong foundation in inclusive leadership that has been helping me to lead and facilitate education projects since I was a graduate student. Three leadership principles I will highlight are: *Holding a growth mindset towards leadership, Facilitating effective and inclusive meetings,* and *Building shared ownership and sense of belonging.* The principles of inclusive leadership I learned in the PDP feel very valuable to me because they offer a guide for how to enact my own deeply held values in team settings. I will share how I learned these principles in the PDP, and how they show up in my work as Co-Director of an astronomy summer school and facilitator for a physics equity project.

I participated in the PDP four times: once as a design team member, twice as a DTL, and once as an Apprentice Instructor. As a DTL, leading small teams of graduate students to create inquiry activities for two different educational settings, I especially learned about practical aspects of leading meetings and project management, through practice, reflective discussions with other DTLs, and support from PDP Instructors. I led team meetings; liaised with stakeholders; scaffolded our work and made sure it was high-quality, completed on time, and honored all member's contributions; and I worked to help all team members to have a positive learning experience. In my first team, I also addressed significant conflicts with one member and a host professor. I received support from PDP Instructors around these issues: asking for outside help is another leadership aspect I developed in the PDP.

As an Apprentice Instructor, I learned about inclusive facilitation through co-facilitating two round-table instructional discussions for PDP participants.

Our cohort of Apprentice Instructors discussed a reading about facilitating discussions, then debriefed after each discussion. I practiced paying attention to who had been contributing a lot and who could contribute more; watching others' body language and intentionally using my own; using shared note-taking to regulate the pace of the discussion and make sure everyone's contributions were valued; and considering our goals and time to make in-the-moment decisions about whether to follow an unexpected conversation thread or bring us back to the goals. This facilitation is a form of leadership: I was in charge of supporting others towards my/our learning goals for the discussion. I loved it: I felt a sense of flow, and I continue to love facilitating discussions.

These experiences in the PDP gave me both a foundation of leadership skills and a *growth mindset towards leadership* that has continued to support my development as a leader. I learned that there is a wealth of research on leadership, and that leadership can be intentionally improved with study, practice, reflection, and feedback — like any other skill. You don't have to be a "born leader."

The first context where I'll describe inclusive leadership is as a Co-Director for the Pan-African School for Emerging Astronomers (PASEA: https://www.paseaafrica.org; Strubbe et al., 2021). PASEA is an inquiry-focused short course in astronomy for African university students that I co-founded in 2013 and have held biannually since. In its first year, I established PASEA as a teaching venue for my PDP team, and led (as a DTL) a team of three graduate students in designing the inquiry activity that we have used in each school. Our program has since grown to a team of twenty volunteer instructors, two-thirds from Africa.

Practical aspects of *facilitating effective and inclusive meetings* are crucial for the functioning of PASEA. Starting as a DTL, I've learned that these are (sometimes hidden) skills that one needs to learn and practice, even as they may seem obvious once you know them. We have learned to schedule our

monthly team Zoom meetings far ahead and send reminders, pre-plan our agendas, assign pre-work ahead of meetings, collaboratively take meeting notes, identify and reiterate action items, check in on action items at the next meeting, create work timelines backwards from the final goal, and regularly check in on progress with team members. Without all of this, PASEA, as a large and growing project, simply would not happen.

Inclusive facilitation and *building shared ownership and sense of belonging* are crucial in PASEA. As volunteers who meet in person only every two years, keeping up our motivation is essential for the project's survival. We come from very different cultures and are at a variety of academic levels (graduate students through professors), so paying attention to power dynamics is important. Everyone needs to feel value from being a team member and what we're creating together. Growing from my time as a DTL, I want being part of PASEA to be a positive learning experience for everyone. It is especially crucial for me to center *shared ownership* because I am a person from outside Africa trying to support education in Africa: my colleagues (African and non-African) and I have different lived experiences and types of expertise, all of which come together to inform our goals and activities. I strive to support motivation and shared ownership through co-creating an evolving shared vision for our work that everyone believes in, expressing appreciation for everyone's contributions, making sure everyone's voices are heard, and offering understanding when members can't contribute at certain times. We foster a sense of belonging by taking time for personal check-ins at the beginnings of meetings and celebrating each other's successes. When we meet in person, we make time for fun activities together.

The second work context where I'll describe leadership is as a Facilitator for the APS-IDEA project: American Physical Society - Inclusion, Diversity and Equity Alliance (https://www.aps.org/programs/innovation/fund/idea.cfm). APS-IDEA is a network of about 100 teams working to advance equity and inclusion in their physics and astronomy departments. My role is to facilitate monthly Zoom meetings for four teams from Australia, Germany, Nigeria, and Spain. The purpose of the meetings is to provide mutual support for their equity efforts through, e.g., discussing cultural change strategies, creating goals and action plans, and celebrating successes and supporting each other with challenges.

Facilitating inclusive meetings is the key feature of my work in this role. I begin each meeting by asking participants to introduce themselves and checking in how we are feeling today. I sometimes share my own personal challenges in order to offer and model honesty and connectedness, and to welcome others to share their whole selves, including vulnerable parts. We review our co-created ground rules for positive conversations. These are all to foster a sense of belonging, care, and safety that can help us support each other's well-being and allow for more open and productive conversations about potentially challenging ideas in equity.

In the body of the meeting, I use many techniques I learned as an Apprentice Instructor. I summarize and affirm what people say and occasionally bring in a follow-up question or challenge point. I help the discussion stay connected to meeting goals while allowing enough flexibility to follow an unexpected thread if it feels valuable. I pay attention to who has been speaking a lot, and whom to encourage to participate more, especially students. (This is also to model and support the APS-IDEA principle of "shared leadership," encouraging contributions and leadership from members across all demographics and all levels of the academic hierarchy.) I pay attention to body language, even though only in Zoom windows. At the end, I summarize the main points and ask participants what they are taking away. I follow up with members who did not attend, to make sure they are OK and see how we can help them to participate. All of these moves are to help participants feel belonging, support and

agency in the group, and ongoing motivation to engage in their equity work and APS-IDEA. I view all of these as pieces of inclusive leadership.

Last, it feels interesting to be in the meta-role of leading this panel about inclusive leadership. I am intentionally trying to facilitate effective and inclusive meetings, build shared ownership of our paper, help everyone to feel valued for their contributions, present myself as a credible leader, and continue to learn leadership from the experience. That we all have similar expectations of how inclusive leaders and teams work together contributes to a positive and smooth collaboration.

3. Leadership in teaching a project-based online course —Mia Bosinger

During the two years I participated in the PDP, I learned so much about inclusive leadership, not only from leading a design team, but also from the activity design and watching how leadership was modeled throughout the PDP. I was able to take many of the principles we learned through the lens of leadership and apply them to teaching.

I have had the opportunity to apply the leadership principles I learned in the PDP in many areas of my life, particularly in my role as an adjunct teaching professor of a master's level, project-based, online bioinformatics course. My leadership training has been instrumental while teaching this course, especially in the design of the course and when facilitating students while they work on the semester-long group project. Strong leadership can benefit students greatly in this type of group project setting, because it can provide support necessary for them to succeed, while also allowing them freedom to learn through their own trials and tribulations. I've found that, as an instructor, creating an inclusive leadership environment for students to learn in is crucial to student success and wellbeing. In my online bioinformatics course, this is achieved through *building shared ownership*, motivation,

and autonomy. Other leadership principles that have been vital in my course have been creating a *credible leadership image* (as was discussed in Chemers, 2001), trust, and a positive relationship with the students.

The first step in the group project is determining which question to study. I have implemented an online gallery walk, similar to what was used in the PDP during an inquiry activity about Light and Shadow (see Hunter et al., 2010), where learners ask questions they may want to investigate, the facilitators sort the questions by topic, and then hang them on the wall. Learners are then able to stand near a question they are interested in working on and form groups based on where they are standing at the wall. For my online course, I implemented this using a Google form and an online discussion board where students can see all of the questions and comment on those that are of interest to them. They then use this discussion board to form the project groups based on their interests. This gives the students both *shared ownership* over the project and motivation to begin studying the topic.

After the topic is decided upon, students have a great deal of autonomy as to how to answer their question. The project has some basic guidelines, such as, they must use at least four bioinformatics tools and must submit a 5-page paper, but the students decide all of the details of the project on their own. They work together to determine which tools to use, how to divide the work, and how to use the results from the bioinformatics tools to answer their research question.

This level of autonomy is only possible with proper scaffolding, which was modeled throughout the PDP. Each week, the students complete problem sets, which introduce new bioinformatics concepts and tools that may be useful when answering their research question. These are similar to the "starters" that were modeled in the PDP's inquiry activities (see Kluger-Bell, 2010). They guide the students by giving them some ideas about how they could start working toward answering their question. Students

often use some of the tools introduced in the problem sets to answer their research question and also find new tools that are specific to the question they are working on. The project is also scaffolded through a weekly discussion board. These discussion boards help the students to stay on track and guide their thought processes on the project. Some examples include a project proposal, an annotated bibliography, a list of figures, and prompts about their hypothesis and how they plan to prove their hypothesis. This scaffolding is essential to ensure that the students are reaching the learning objectives in the course, while still having a sense of autonomy and ownership over their work.

Another strategy to ensure students feel shared ownership, motivation, and autonomy is through the way in which the work is divided. Students decide how to divide the work, which allows them to work on aspects of the project they are most interested in, giving them a greater sense of motivation. Work is also often divided based on team members' skills, allowing them to work on aspects of the project they are most comfortable with. Because the project is very open-ended, similar to the PDP's inquiry activities, students have the ability to work in ways that are best suited for their learning style, creating a more inclusive environment.

In addition to creating an inclusive environment through shared ownership, motivation, and autonomy, it is also important for me to build a positive relationship with the students, trust, and *a credible leadership image*. Building a relationship with students is especially challenging in an online course. I always begin the course with a pre-recorded video introducing myself. I tell them about my background, interests, family, and hobbies. The students are then asked to introduce themselves in an online discussion board. This process helps begin a dialogue between myself and the individual students relating to their academic and personal interests. I continue to build a relationship with the students throughout the course with thoughtful comments, emails, and virtual meetings or office hours. In the

PDP, I learned how important it is to be friends with the people you are leading, and this is also possible in teaching, even in an online course.

While building a friendly relationship is crucial to effective leadership, it is also important to have a *credible leadership image* and build trust. Credibility is initially established in my introduction when I discuss my academic background and credentials. I continue to build this credibility throughout the course by exhibiting expertise in the course material, and being honest when I do not know the answers, which was modeled throughout the PDP. If there is a question that I do not know the answer to, I will always look it up and get back to my students. I make notes during virtual class meetings and always follow up if I said I would. I also respond to emails promptly and thoughtfully. These gestures show students that I am reliable and dependable, and help to build both credibility and trust. I also share explicitly the intent and goals of my assignments, which is something that was modeled in the PDP. I believe it builds credibility, trust, and motivation when students know why they are being asked to do something and how it may benefit them. Each of my assignments lists which of the course objectives are addressed in the assignment.

These leadership principles are vital in my role as a professor and allow me to make the course as inclusive as possible. Many of the principles of leadership we learned in the PDP overlap with the training we received about teaching. Applying what I learned in both of these areas to my online course enables me to meet the course objectives, while giving the students an opportunity to take an active role in shaping their learning. In addition, students are invested in the course because they feel a sense of ownership, motivation, and autonomy, and they are satisfied with the course outcomes because I built trust, a credible leadership image and a positive relationship with the students.

4. Leadership in pre-college teaching and administration, and college education
—Heidi Stauffer

The leadership training I received during my time with the PDP has given me invaluable tools and skills to use during graduate school and beyond, helping me as I develop into an effective leader in my current position. Because I've always had a passion for teaching and sought out opportunities for experience, I had already been using some effective methods to teach. But my training in the PDP showed me why those methods work and the research behind those methods. In some respects, the PDP training has shaped my own goals for my future and played an important role in the choices I have made and continue to make in my career.

PDP training has helped me incorporate several leadership concepts into my work: *building shared ownership*, *facilitating inclusive and effective meetings and classes*, and consciously building inclusivity into the frameworks for meetings, lessons, and more broadly, the communities I am involved in. These concepts, as well as developing leadership in others, are foundational to my current work. Equally important, the PDP training helped me to realize that in terms of leadership specifically, I can continue to improve my skills, develop new skills, and learn from applying what I've learned. This relates directly to developing a *growth mindset towards leadership*.

I will discuss my specific training in the PDP and how this training has shaped my path as an educator, and how I use what I've learned in my current position as Science Professional Learning Community (PLC) Lead and science and math teacher in a private middle and high school, and as a science lecturer at a local community college.

My first PDP experience was as a member of a design team which developed a new multi-day workshop for transfer students in the sciences. I served as a DTL twice, once for the workshop I helped develop, and once where I led a design team to develop an inquiry activity from scratch. I was also part of a special projects team working on diversity and inclusion, and on creating a framework for a facilitators handbook. Being a DTL is where I learned by doing two of the fundamental principles of leadership: *facilitating effective and inclusive meetings*, and *building shared ownership* in the project at hand. I learned that I can ask for help, and that communicating with inclusive language and perspective are key components in creating shared ownership. Leading my second DTL team proved challenging, but that experience taught me the most. I admittedly had the most difficult time creating an environment of shared ownership and belonging; without that aspect, effective and inclusive facilitation cannot happen. I was grateful for more experienced instructors and staff members who helped me present the project as a collaboration specifically within the framework of the PDP, which would be the foundation for our own unique creation. Once my team was on board with that approach, meetings ran smoothly.

During my experience as a special projects team member, I was able to see the behind-the-scenes aspects of leadership, learning how to create effective facilitation and inclusive discussions on sensitive topics. For one special project involving equity and inclusion, I helped facilitate a discussion on equity and inclusion. I learned to be conscious of body language to determine when someone in the group was uncomfortable or if I needed to gently guide the discussion back to the topic at hand. The other special projects team involved facilitation specifically and creating a framework for a facilitator's handbook. This experience gave me invaluable insight into effective and inclusive methods for leading meetings, discussions, and classes.

In terms of my career path, my experience in the PDP helped me to realize that I truly love teaching science. Due to family circumstances, I was unable to follow a traditional research career in academia,

but my experience with the PDP helped me make the transition into teaching science in college and pre-college settings.

As the lead for my school's Science Professional Learning Community (PLC), I am applying what I learned in the PDP on a daily basis. My school, Lydian Academy, is a small private school and because of our size and the fact that many of our teachers teach across disciplines, we have formed PLCs instead of more formal departments. As Science PLC Lead, my responsibilities include updating and streamlining the school's curriculum to align with Next Generation Science Standards (NGSS Lead States, 2013; K–12 science content standards), mentoring newly hired and veteran teachers, working with the Science Lab Manager to add to and maintain the science lab curriculum, and lead the Science section of the school's professional development trainings, typically two to three times a year. Also, over the past two years, I have been focused on collaborating with my fellow science teachers to update the syllabi for all the science courses.

As Science PLC Lead, I consider that my primary responsibilities are to guide my fellow teachers to be the best teachers they can be, and to encourage them to take initiative and use their expertise and experience to help other teachers. In this way, I aim to help them become leaders themselves in the context of science education. To those ends, I've found myself using many of the concepts I learned in the PDP, especially *building shared ownership* and *facilitating inclusive meetings*. As an example of building shared ownership, while working on updating the science course syllabi, we formed teams of two, with one veteran teacher and one newer teacher, to work on specific course syllabi, and additional teams of two teachers to streamline a particular resource (such as lecture slides) for a particular course. The idea was that having teachers collaborate on curriculum resources that all science teachers could use would give them a sense of con-

tributing to a larger collection of resources that belong to all of us. In addition, I spend some time conducting peer reviews of my fellow science teachers, where I observe them teaching a class, the primary goal of which is to collaboratively collect best teaching practices to be shared during professional development meetings.

Overall, I value my training in inclusive facilitation because I've used these skills leading the Science PLC component of our professional development meetings, and in less formal meetings with teachers. I'm always conscious of ensuring that everyone who wishes to contribute has a chance to do so, and that comments, questions, and suggestions for improvement are acknowledged and considered.

As a lecturer at a local community college, I developed a virtual course for an introduction to geology class, which has been taught both synchronously and asynchronously. My main goals were to involve the students in guiding their own education, incorporating aspects of *facilitating inclusive classes*, and creating a course framework that is accessible. As an example, I created assignments that encouraged students to relate geology to their own lives, including their final project where they evaluated the geologic hazards around the place where they live. Even though the course was virtual, I was clear to set the tone and ground rules with every assignment and in every class meeting, something I learned during my PDP training. As an example, for every online discussion and in their peer reviews, I reiterated my ground rules for engagement, specifically to be respectful and offer suggestions. This approach seemed to work very well, as most of the students participated in the online discussions and were all insightful and very respectful.

5. Leadership and project management at science non-profits
—Max Tarjan

As a graduating Ph.D. applying for jobs, I found the name "Professional Development Program" to be vague for a CV. But as I applied what I had learned in the PDP as a director at a non-profit, I realized that this generalized name is quite apt. The skills transcended the undergraduate classroom, and I found myself sending out training materials to colleagues in both academia and non-profits and offering crash courses in facilitating discussions.

The ways in which the PDP influenced my work are even more numerous than the roles I occupied while associated with the PDP. Attracted to the prospect of five days in Hawaiʻi (where the PDP was held for many years), I started as a participant in 2011. I then acted as a Design Team Leader in 2012–2013 and 2015. I was part of a task force to document facilitation strategies, where we sat silently taking copious notes on the actions of staff as they facilitated discussions (us "shadowers" were likely as unnerving to the instructors as the accepted name implies). Those notes contributed to the "Guide to Effective Meetings" that was used by the PDP in subsequent years and I later brought to the staff at a science non-profit. As I transitioned from graduate school to the workforce at a science non-profit, I acted as a PDP Apprentice Instructor (2015) and Instructor (2016–2019). In 2021 I worked on a team in the "Leading By Design" strand with the goal of adapting PDP materials to new contexts. I adapted a discussion about leadership theory and practice from the PDP to be used in any (academic or non-academic) setting, and piloted it at the science non-profit where I worked at the time.

As a director at a science non-profit with extensive project management responsibilities, direct reports, and collaborators, I drew extensively on the skills acquired through the PDP. Key leadership approaches that I took from the PDP include *facilitating effective meetings* by providing context, being aware of non-verbal communication and using the approach of backward design to stay on task; and *developing a credible leadership image* through reliability.

"Shadowing" discussion facilitators at the PDP taught me how to *facilitate effective meetings* that move participants to agreed-on goals. What I learned proved important when working on a team to come up with new research ideas, making decisions as a group, and helping volunteers to make valuable contributions to citizen science projects. Some notable learnings include: 1) Context is key. Prior to entering a discussion, give detailed context for the role of the facilitator and the expectations for participants. Never assume that participants come to the discussion with the same expectations for engagement. Telling participants that, for example, one goal of the discussion is to hear from every person — so you may need to wrap up a comment from one person and elicit a comment from another — will make the participants more open to this type of intervention, and your job as a facilitator much easier. 2) Monitor your reactions and use your body language to your advantage. For example, allow yourself to get comfortable with a long pause; this gives people a chance to think and contribute. Strategic orientation of your eyes or body can communicate when you want participants to engage with each other directly (look down to your notes to discourage one-on-one conversations with you) and when you need to transition from one speaker to another. 3) Most importantly, the "leader" of the discussion is *not* necessarily the lead contributor. Your goal as a discussion facilitator should be to help the group communicate their thoughts, not exclusively hear yours.

Backward design (Wiggins & McTighe, 2011) is an approach taught in the PDP that involves starting with your teaching goal and the outcomes of learning, and then building the activity or lesson to support that learning and elicit evidence for evaluating

learning. This approach is presented as an aid for effective teaching in classroom settings, but I have found it applicable in the broader context of facilitating group work. Starting with your goal and making decisions with the goal at the forefront is a valuable approach across contexts. The mental pattern of backward design was drilled into my habits when I used this approach as a Design Team Leader and then coached participants in its use as an instructor. This approach is what kept the team on task and kept the team moving toward progress on a tight timeline. In the workforce, I often recognize myself using the same mental pattern to keep my team moving towards the goal. Returning to the goal of the discussion often helps to resolve questions when my team gets lost in the weedy details of a problem.

Just as members of the workforce need to be viewed as credible to be trusted with important work, DTLs need to *establish a credible leadership image* to get buy-in from their team and steer them to a successful outcome. Teammates must trust that the leader is capable of delivering the promised results for them to stay motivated. One way to garner this trust is to consistently put in deliberate effort to be prepared to meet the team's needs. For example, PDP instructors advise DTLs to complete background research on their STEM content prior to meeting with the team. DTLs are given structured opportunities to reflect on what needs to happen at the next meeting, and how they will accomplish the objectives with their team. There is an emphasis on preparedness, timeliness, and reliability that garners trust in the process and the leadership of the program. DTLs get practice with planning an agenda for students, often with guest speakers, field trips, and other components that require forethought and organization. This experience prepared me for project management in a non-academic organization and allowed me to practice systems to consistently accomplish tasks in a timely manner. In my experience, these behaviors garner trust from others and result in the conference of greater responsibility.

These examples illustrate a fraction of the impact that leadership training in graduate school has had on my success in the workforce. As an instructor for the PDP, I became interested in offering professional development to others. In doing this opportunistically outside academia, I recognized the need for this training in Ph.D. programs. Full-time employees often don't have the flexibility and time for a 100-hour experiential learning opportunity such as the PDP. In sharing my knowledge with colleagues, I found myself trying to condense what I gained across years of experiential learning into a 30-minute crash course. With only a fraction of graduating Ph.D.s pursuing an academic track, training in broadly applicable skills like leadership and teamwork should be part of the graduate student experience. I will always be grateful for the skills and community that I gained in the PDP.

6. Summary and recommendations

Through our four stories, we have shown that inclusive leadership skills are important for STEM professionals across a diversity of careers. We have also shown that it is highly valuable to give leadership training to STEM graduate students and postdocs, exemplified by our experiences in the PDP. We connected our experiences of learning and using leadership skills to four leadership principles: (1) Holding a growth mindset towards leadership, (2) Facilitating effective and inclusive meetings and classes, (3) Building shared ownership and sense of belonging, and (4) Building an image as a credible leader.

Audience discussion during our conference panel centered on motivation: how to motivate others towards a shared goal, how to help students maintain motivation during a long project, and how to keep oneself motivated in the midst of many other work and life situations and pressures.

In conclusion, we advocate that STEM graduate school and/or postdoc programs should include experiential training in inclusive leadership. From our experience, we recommend that this leadership training should include: (1) Integration with an authentic experience of leading colleagues towards a concrete authentic goal; (2) Research on leadership, including highlighting equity and inclusion in leadership, and principles of inclusive leadership (e.g., the four highlighted in this article); (3) Self-reflection, reflection, and formative feedback with colleagues and "experts" on leadership, and the opportunity to incorporate these back into practice; and (4) opportunities to learn how leadership can be important in a variety of STEM careers.

Acknowledgements

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