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Special Section:
The Future of Critical Zone Science: Towards Shared Goals, Tools, Approaches and Philosophy

Equity, Diversity, and Community as the Basis for Critical Zone Science and Education

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Key Points:

- To address low "racial" and ethnic diversity in critical zone science, we must center diversity, equity, and community at the outset of work
- This work requires intentional and continuous learning and flexibility, as well as a willingness to step out of one's comfort zone
- Team science practices and tools can help put these values in practice and offer support when (not if) we fall short

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Abstract Responding to the social and environmental challenges of the Anthropocene requires that we integrate science across multiple perspectives, approaches, and disciplines in equitable and culturally responsive ways. While critical zone (CZ) science has made large strides in bridging natural, social, and education science disciplines, the field has been slower to address the lack of diversity, especially in terms of "race" and ethnicity. This means that CZ science and education do not fully reflect all communities they must serve, and representation and access to careers in the field therefore remain limited to mostly white individuals. Despite best intentions, predominantly white science and education teams frequently consider values such as diversity, equity, or inclusion in later stages of work instead of centering these values as the foundation from the outset. Here, we reflect on how our CZ Collaborative Network Project has both struggled with, and is learning to, authentically center and uphold our values in our own work. Our goal is to normalize the concept that culturally responsive CZ science and education requires intentional trust and relationship building, flexibility, and continued learning. To support our evolving work, we have relied on team science practices, and we offer insights into the strategies and tools that help us with our aspiration to center and integrate our values of diversity, equity, and community into team processes.

1. Introduction

All of life depends on a thin, porous layer of the Earth's land surface known as the critical zone (CZ; NRC, 2001). This zone extends from the top of the vegetation canopy or built environment, down to the bottom of freely circulating groundwater—the top hundred or so meters of depth—or about 0.001% of the total distance to the center of the Earth (Giardino & Houser, 2015). To put this in perspective, if Earth were an onion, this portion of the Earth's surface would be even smaller than the outer shiny skin. Even though the term was not used until very recently, this narrow CZ has supported the evolution of life for millions of years and is critical for human survival (Field et al., 2015). The CZ provides the resources to feed and clothe societies and provides humans with drinking water. The soils within the CZ support agricultural food production and provide a foundation for urban centers and infrastructure. Additionally, the CZ regulates global climate through the "breathing of the biosphere," wherein carbon dioxide is removed from the atmosphere by photosynthesis and released back into it by ecosystem respiration (Chorover et al., 2011; Perdrial et al., 2015). Improving our scientific understanding of CZ functions is considered essential to solving contemporary challenges, such as mitigating and adapting to climate change, managing water supplies sustainably, and feeding the 10 billion people that will be sharing the land surface by 2050.

According to the National Science Foundation's (NSF) Next Generation Earth Systems Science research priorities, integrative Earth systems science conducted by diverse science teams is necessary to solve the complex problems that often intersect multiple academic disciplines:

> "*Essential elements of an integrated approach for understanding the Earth's systems emphasize research on complex interconnections and feedbacks between natural (e.g., physical, chemical, biological) and social (e.g., cultural, socioeconomic, and geopolitical) processes. Such integration will include attention*

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> *to diverse, inclusive, equitable, and just approaches to the research; partnerships and stakeholder engagement; support for computational and observing infrastructure; and support for workforce education and training* (NASEM, 2021a)."

This integration requires removing disciplinary silos and cultivating more diverse, inclusive, and equitable STEM research and education. Since the inception of the CZ science program by the Earth Sciences Division of the U.S. NSF over 20 years ago, CZ science has made important strides, especially in promoting a deliberately interdisciplinary approach. Disciplinary silos were largely removed, and interfacing disciplines (e.g., geomorphology, ecology, soil science, hydrology, geochemistry, and microbiology) were brought together to work, literally, on common ground. More recently, social and education disciplines have also begun to interface with the natural science CZ disciplines. This interdisciplinary approach has resulted in significant advances in our understanding of the CZ (Arènes et al., 2018; Brantley et al., 2017; Lin et al., 2011), and allowed us to foster interdisciplinary science and education across the globe (Singha et al., 2020).

However, in the U.S., systemic racism has prevented students from diverse backgrounds from being educated in STEM fields including CZ science (Chang et al., 2014), and research has not been particularly culturally relevant to a large portion of U.S. society. In fact, CZ parent disciplines such as environmental science and geoscience have some of the lowest participation rates for African Americans, Hispanics, Native Americans, LGBTQ+, women, and people with disabilities working in science and engineering (Gonzales & Keane, 2020). The percentage of Black, Indigenous, and People of Color (BIPOC) with geoscience degrees who are working as geoscientists decreased since 2010 from 23% to 15%, while the percentage of BIPOC with geoscience degrees working in non-science and engineering occupations increased from 28% to 48% over that same time (Gonzales & Keane, 2020). According to the American Geosciences Institute, African Americans working as environmental scientists and geoscientists represent only 1%–7.8% of the total population of geoscience professionals, which limits the reach and impact of geoscience research. Mostly due to increased participation of Hispanic students in these fields, BIPOC received 15.7% of the geoscience bachelor's degrees, 10% of the geoscience master's degrees and 6.7% of the geoscience doctorates (Gonzales & Keane, 2020).

Failure to address systemic racism in all STEM fields including CZ education and research has numerous consequences for the field. First, low diversity means that representation in and access to careers in these disciplines will remain off limits for many groups. As a result, we have continued to exclude certain "racialized" groups from participating as full members of U.S. society, particularly those of ethnic African (Black/African American) ancestry (note the use of quotation marks to signal the constructed and ideological nature of these terms that have no biological referent). In failing to accurately reflect the demographics, questions, and needs of *all* community members, we have also failed to educate, recruit, and achieve a diverse STEM workforce particularly in the geoscience-adjacent CZ science. As a consequence, we have continued to miss out on the unique perspectives and approaches that many talented students and future science professionals can contribute to CZ research and education. As such, the U.S. NSF recommends that "*incorporating broad perspectives, values, and experiences into all stages of research—including from those who have been historically excluded [from CZ Science]—and ensuring an inclusive healthy workplace culture will result in more relevant research questions, more new ideas, more creativity, and more capacity. It will also help ensure that scientific advances yield benefits to all sectors of society*" (NASEM, 2021a). Importantly, the development of more diverse, inclusive, and equitable geoscience pathways will lead to culturally relevant research agendas, deepened disciplinary knowledge and skills, as well as the ability to develop interdisciplinary and transdisciplinary science teams to solve problems (NASEM, 2021a).

This kind of transformation requires deep cultural change in CZ science and education. Recent efforts such as Unlearning Racism in the Geosciences (URGE; Duran et al., 2021) have mobilized a growing group of geoscientists (a parent discipline to CZ science) to actively promote antiracism, diversity, and changing the culture of science more broadly. However, enacting values such as diversity, equity, and inclusion remains a challenge for some white individuals and teams for a variety of structural, cultural, and individual reasons, and this threatens momentum (Morris, 2021).

In this paper, we share experiences of efforts to integrate diversity and equity into a multi-institutional CZ research and education project ("Using Big Data to assess ecohydrological resilience across scales"). Specifically, we report on the partnership between the University of Vermont (UVM), a Predominantly White Institution (PWI) and Jackson State University (JSU), a Historically Black University/College (HBCU) from the perspectives of faculty at both institutions. We describe the necessary learning process of the mostly white UVM faculty to

enable a mutually beneficial partnership between institutions and the effects to the overall project culture beyond the education and outreach team. We outline the development of CZ teacher education programming resulting from this partnership (Section 2) and offer examples of tools and resources that are supporting us in efforts to integrate diversity and equity into CZ research and education projects going forward (Section 3). Lastly, we offer considerations on measures for team and project success in this context (Section 4) and indicate our varied positionality with respect to power and privilege (Section 5).

2. Examples From Our Work: Growing a Partnership Between Researchers and Educators From an HBCU and a PWI

In the following we describe how UVM faculty initiated contact with JSU faculty (UVM perspective, Section 2.1), how this contact initiation was received and led to the development of teacher education programming (JSU perspective, Section 2.2), and how this impacted the team beyond the education team (shared perspective, Section 2.3). Before we present our findings, we acknowledge our varied positionality with respect of privilege and power and point the reader to the positionality statements of all authors at the end of this contribution (Section 5).

2.1. The Perspective of the PWI Team: From Blind Spots to Values and Authentic Engagement

During the proposal development phase of this project, faculty of the education team at the lead institution (UVM) team agreed that inclusion and diversity should be central to education programming, and that faculty from HBCUs should be an essential part of all phases of the program design, implementation, and assessment. Because UVM had a pre-existing partnership with JSU, the UVM team had intended to collaborate with JSU faculty in the development of this programming. Though the UVM team was intentional about the commitment to diversity and equity, specifically in the development of education and outreach components of the project, they did not significantly engage with faculty from JSU or solicit their input in the proposal design phase from the outset.

This is a typical approach of many PWIs when seeking collaborations with ethnically diverse populations, including HBCUs, and it is extremely harmful to those populations. For example, many faculty at PWIs are not aware of differences between HBCUs and PWIs, including significantly higher teaching loads at HBCUs and "minority taxes," that is, the burden of extra responsibilities placed on non-ethnic European faculty in the name of diversity (Campbell & Rodríguez, 2019; Rodríguez et al., 2015). Thus, negotiating workloads and budgets is important at the onset of a project planning phase. When PWI faculty seek to work with HBCU faculty at the onset of the project development phase, an equitable allocation of resources is more likely and as a result, labor of Black faculty is compensated equitably (Williamson et al., 2021). HBCU-PWI partnerships can be mutually beneficial (Allen & Esters, 2018), and excellent examples exist (Gasman, 2008). Generally, programs that have established effective collaborations have taken approaches that follow best practices recommended by the National Science and Technology Council (NSTC, 2021), and the National Academies of Sciences, Engineering, and Medicine (NASEM, 2021b, 2022), such as intentional consultations and community involvement (Barnes et al., 2022). This approach increases the likelihood that planned activities are indeed beneficial for everybody involved, because needs are clarified, and learning is possible.

The time when the proposal was recommended for funding was also the time where calls for racial justice grew loud across the country after George Floyd's murder. By then, the UVM education team had grown and now included faculty working on racial justice and a critical race theorist who specialized in science and education, bringing important perspectives to the team. Some of the previously less aware team members now began to self-interrogate how identity shows up in all aspects of scientific research and education programs. For example, at one of the first meetings, the discussion centered around novel science to address CZ challenges. When the critical race theorist asked, "*why should a Black 3rd grade student care about your science?*," the room went quiet for some extended and uncomfortable moments. Indeed, it appeared that the UVM team had failed to consider the larger context or thought about *who* would benefit from this novel science. In the room consisting mostly of ethnic Europeans (i.e., white), it appeared that no one had centered the context of racism until the critical race theorist's question. Assistance from a non-profit center that works to cultivate transformative leadership to strengthen movements for social justice and the environment was helpful for these early conversations, and the need for continued engagement around values of diversity and equity became clearer.

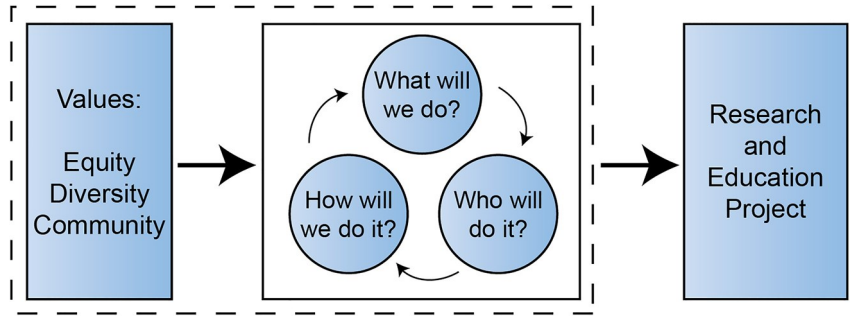

Figure 1. Schematic depiction of values as the overarching guidance for decisions in research and education that can guide research or education projects in alignment with these values.

In the following weeks, the UVM education and outreach team began to have many conversations about personal values pertaining to diversity, equity, inclusion, and community that led to discussions about how these values applied to their work. *Diversity* is the range of identities spanning ethnicity, gender, sexual orientation, and ability that are embodied by the interdisciplinary CZ science team. *Equity* informs how research and education programming is conducted and how resources (e.g., time, research funding, or co-authorship) are fairly allocated. *Inclusion* is a typical value in this context and the team had important discussions about the difference between inclusion (i.e., inviting somebody to a table i.e., already set) and co-creation (i.e., setting the table together (Finney, 2014)). Ultimately the team settled on *community* (instead of inclusion) to be a better expression for the practice they aspired to, that is, co-creation of research and education programs with emphasis on process and the human experience by intentionally allocating time and energy to relationship and trust building (Greenhalgh et al., 2016) and in response to the critical needs of the various communities science and education seek to serve.

When these values are considered in the ideation phase of a project, that is, they constitute a key ingredient (akin to flour in a cake instead of the decorative cherry on top), all relevant questions will be addressed in alignment with these values (Figure 1). This includes considerations of critical needs (i.e., value of community), how we conduct our work (i.e., value of equity) and whose perspectives are represented in the team (i.e., value of diversity) (Harris et al., 2021; Van Horne et al., 2022).

Through this process, the team clarified the important role of developing intentions and building relationships as cornerstones for the partnership with JSU in line with these values. The intentions for the partnership with JSU faculty summarized below constituted the key aspect of the initial outreach to JSU:

We strive to generate a culture where CZ science and education is not only accessible to, but strengthened and shaped by scientists, educators, and learners of all identities and cultures. Our intentions are to:

- *Develop an education and outreach partnership between JSU and UVM,*
- *Create a collaborative space for JSU and UVM students and faculty to build relationships and gain first-hand experience with CZ and data science,*
- *Generate norms that value and honor the voices of all participants in science, specifically in researching and learning CZ and data science,*
- *Ground our understanding of science in real world applications that are socially and environmentally responsible.*

2.2. The Perspective of the HBCU Team: From Skepticism to Partnership

The initial outreach on the part of UVM team members to faculty at JSU was not uncommon, as HBCUs are often contacted with invitations to participate on federally funded projects aimed at broadening participation. Unfortunately, invitations from PWIs have long been met with skepticism and suspicion for the reasons outlined here. Generally, collaborating means that the HBCU researchers/scholars provide access to students or teachers who engage in pre-defined projects, or the HBCU is given a small sub-award to implement an education program and share data with the lead institution, which is the site of the core scientific research, the site of the bulk of the research expenditures, and the site of the most significant research publications. The diversity-focused collaborations have not always been mutually or equitably beneficial; in some prior experiences of the JSU faculty, these

collaborations have been primarily for the purpose of checking off a diversity box on a grant-funding application with very little intention of doing the work of establishing true science and learning collaborations. This is the knowledge that informed the UVM faculty prior to engaging with JSU faculty as collaborators, co-creators, and decision makers. However, it was also this knowledge that subsequently made UVM faculty both aware of and determined to not repeat the same well-documented mistakes just recounted. To be clear, even with the best of intentions, the UVM team did not engage with JSU faculty during the proposal development phase, similar to other PWIs in the past. However, unlike those PWIs of the past, UVM faculty recognized the lack of co-creation as an issue and sought to address it. The opportunity to collaborate came with an invitation to engage in the process of reshaping the educational outreach program so that it best fit the areas of expertise of the JSU faculty and targeted the areas of greatest need among their K-12 in-service and pre-service educators (NRC, 2012). The collaboration also came with opportunities for JSU faculty to share their hesitation and to negotiate the boundaries of the partnership. For example, access to financial resources allowed the JSU researchers to purchase equipment needed to support their work and to devote time during the summer to their scholarship rather than to teaching. It is, for example, common for HBCU faculty to teach year-round (i.e., 12-credit hours per semester and 6-credit hours during the summer session); thus, having financial compensation allowed JSU's researchers to have the flexibility to devote much-needed time to scholarship during the summer months to write and revise manuscripts.

Team cohesion was reinforced by genuine strides toward building relationships (a learning partnership) in which trust and open dialog were essential, and differing perspectives on the value of CZ Science for K-12 Educators and pre-service teacher candidates in Mississippi (MS) could be explored. The process of working in a partnership across institutions resulted in the co-creation of the "CZ Science Teachers' Academy." The Academy team is composed of eight faculty from different disciplinary backgrounds and institutions: *Computer Science, Engineering, Ecology, Biogeochemistry, Hydrology, American Cultural Studies and Ethnic Studies, STEM Education, and Educational Administration.* This team developed a professional learning experience for 5th and 6th grade science teachers in MS, allowing UVM CZ scientists to partner with specialists in broadening participation from UVM and allowing JSU to provide professional learning experiences on integrating CZ science and culturally relevant teaching practices into the learning experiences of African American 5th and 6th grade students. The project activities were designed to achieve the following outcomes: increased understanding of CZ science, MS and Next Generation Science Standards, culturally relevant (sustaining) science education, and inquiry-based and community-based science, as well as increased access to resources and support to implement CZ lessons in 5th-6th grade science classrooms in MS. The overarching aim of the CZ Academy was for participants to be equipped and empowered to use CZ science and inquiry-based teaching practices to engage students in lessons that position them as advocates for environmental justice and as investigators who seek to understand and solve local environmental problems.

This Academy grew out of expertise and activities from previously funded projects at UVM such as the Champlain Research Experience for Secondary Teachers funded by the federal GEAR-UP grant and broadening participation activities at JSU. The CZ Academy was also something new—something forged at the intersection of the JSU-UVM collaborative science team. In the process of co-creating the CZ Teachers' Academy, we were intentional about leaving room and flexibility for the teachers who were actually in the classroom to help shape the program. As part of the application process, prospective participants were asked questions to help gauge the level of familiarity with key program objectives. They were asked to submit sample lesson plans and provide insights into their motivations for being involved in a project such as this. Their preliminary feedback aided in the selection of participants and in the planning process for the initial CZ Academy Virtual Workshop. As a team, we underestimated the critical needs that participating teachers would bring to the program once they officially joined the learning team. This preliminary work re-emphasized for all that community engagement needs to be at the forefront of our education and research efforts, as does the need to build in the necessary flexibility that responds to the critical needs of our participants.

For instance, the need for resources to support creative science experiments, particularly for those teachers serving in rural MS school districts, as well as access to local experts who could support curriculum and teaching on topics related to water, air, and soil quality and human-environment interactions emerged as the most critical needs of teachers during initial CZ Academy workshops. Teacher needs were further articulated in their responses to the pre-academy survey where teachers were asked to rate the extent to which they integrated the following key features of CZ Science into their science instruction: inquiry and place-based pedagogy, backwards instructional design, scientific or mathematical modeling, engineering design, representing and interpreting quantitative data,

making inferences and justifying conclusions based on data and observations, and implementing culturally relevant pedagogical strategies. In each instance, about 50% of the teachers indicated that they used these techniques to a very small or moderate extent, which is in agreement with findings in studies on teaching STEM disciplines (Toolin et al., 2022). The pre-academy survey also confirmed some of our assumptions about what topics needed to be addressed in the teacher academy; however, our decision to allow time for the teachers to give voice to the things that they deemed to be the most relevant priority areas was a critical aspect of our ability to pivot as needed to reorient the professional learning experiences offered during the academic-year virtual workshops and in the summer research site visits. One significant modification was to organize the monthly workshops so that they were conducted by one UVM and one JSU faculty member; the objective here was to help the teachers see JSU faculty/scholars as local resources that they have ready access to. Additionally, the academy team modified the structure of the sessions to include both asynchronous readings and activities to be completed prior to the workshop as well as synchronous activities such as relationship building, sharing examples of teaching experiences, practicing place-based instructional strategies, and brainstorming ideas for connecting local issues to science standards. The team also opted to plan the summer experience so that MS teachers had opportunities to travel to Vermont to engage with K-12 educators there.

2.3. Beyond the Education Team: Shifts in Project Culture

Having been ethnically homogeneous initially, the UVM project demographics diversified and it was this change that provided a learning opportunity about the legacy of racism and discrimination in the U.S. While this work was mostly spearheaded by the education team, the entire CZ project, including science teams, began to engage in important learning around identity, "race," and anti-racism. It became clear that for some team members, these conversations were completely new, and for others, the integration of "race" into research discussions was new. The latter situation usually occurs because, as was the case in our project initially, discussions around diversity are often held by a subset of people, separately from discussions around science and/or education (Levine, 2021). However, discussing core motivations and questions of who we serve forced the growing team to clarify values and to disrupt an old pattern that was familiar to many. For example, we discussed how narrow perspectives on how research and education should happen can minimize benefits for society. Additionally, we interrogated the common assumption that engaging with values of equity, diversity, or community would take time and resources away from the "real" science, thus slowing progress.

Over time, our team has learned that there is a wide gap between communicating values of diversity, equity, and community and enacting these values. To practice and fully embrace these values requires introspection, engagement, the willingness to change behaviors, and a commitment to hold ourselves accountable when (not if) we fall short (Brown, 2018). As a growing team, we fell short of these aspirations on a variety of occasions. Moving forward, when hard conversations present themselves, we continue to explore ways of learning in the spirit of working towards impactful research and education. This also illustrates why we mentioned that "trust" is a necessary ingredient in any collaboration. However, to establish trust we needed to build relationships and have direct and purposeful conversations about our shortcomings and how we collaborate. Presently, both UVM and JSU faculty understand that inadvertent "mistakes" are going to happen and that discussion and forgiveness of these learning stumbles is necessary for effective and impactful collaboration.

3. The Tools to Help Us Get There: Our Work in Progress on Team Science

Putting values of diversity, equity, and community into practice is not automatic or easy. For our team, diversity includes a variety of identities spanning "race," ethnicity, gender, sexual orientation, and ability that bring a variety of perspectives into our work. Common challenges of such diverse science teams include the potential for miscommunication and lack of trust among members, lack of meaningful integration of knowledge from different disciplines to create new frameworks and methods, team goal misalignment, geographical dispersion among team members, and delays in research progress when tasks depend on multiple team members (Martin et al., 2022; NRC, 2015; Stephens & Stephens, 2021). Additionally, for teams that aspire to be diverse along lines of "race," gender, and ethnicity, there is frequently potential for inequity in terms of engagement, leadership roles, and authorship (Hammer & Miaskowski, 2017; Lerback et al., 2020).

In an attempt to address these challenges and build a supportive project culture within our team, we have chosen to intentionally and critically evaluate how our identities and experiences shape the way we value and do science

and education and navigate the world in general. This ongoing process has required some to step out of their comfort zones, be open to mutual learning, and dialog about systemic barriers that prevent us from enacting our collective values. For many of us, this means acknowledging that scientists and educators with certain identities benefit from systems of white supremacy and patriarchy, while other team members are negatively impacted. To support our ongoing efforts, we have taken advantage of insights and tools that team science researchers and other science teams have offered to support the creation and maintenance of effective teams capable of achieving high standards and centering our values (e.g., Cheruvelil et al., 2014).

In the following sections, we share recent findings from team science and examples of the behaviors and interactions that we aspire to in our work, including team leadership, team member characteristics and team composition, and team interactions. We refer to our own U.S.-based project to exemplify applications of these tools; however, they are applicable for projects across the globe. Further, while these findings apply to any team in a wide variety of fields, we posit that these tools are useful in the growing field of CZ science that will be strengthened by the perspectives, knowledge, and skills of scientists and educators of all identities.

3.1. Considerations on Team Leadership

In lieu of a comprehensive review of the large body of leadership-focused literature, we offer a few thoughts on the role of leadership in upholding our team values (Brown, 2018). One key process in value-centered team science is reflecting on the role of and addressing issues of identity and privilege, especially for team and project leads. The majority of leaders in the geosciences have historically identified as white (and often male) (Bernard & Cooperdock, 2018; Marín-Spiotta et al., 2020). Part of the privilege of this group is the option to avoid engagement with identity and frequently this group is absent from training and service focused on diversity, equity, and inclusion (Jimenez et al., 2019; Patton & Bondi, 2015). As a result, the likelihood that white scientists and educators will fail to identify and address racism is high (Dutt, 2020). In the absence of introspective and intentional leadership, it is more likely that leaders will foster inequity by requiring women, and more often persons of color, to do a disproportionate amount of unpaid labor to educate their peers (Jimenez et al., 2019). Thus, white leaders must continually invest time and energy into introspection and self-education to promote a value-centered culture in projects and teams. White leaders also have little incentive or pressure to do this important work, while scholars of color carry most of the burden without being compensated (Patton & Bondi, 2015). Some in our current research and education culture incorrectly claim that devoting resources (time, energy, headspace, money) to DEI is detrimental to progress and efficiency. The question therefore becomes: how do you change this culture? Cultural shifts are needed to address these issues. URGE, a bottom-up, grassroots initiative, guided volunteering geoscience groups through a curriculum to identify issues and acquire data on their institutions (demographics, current policies etc.), and to develop a clear plan of action to make institutional changes (Duran et al., 2021). This culture change, however, cannot rest on voluntary engagement alone, but requires accountability to implement changes across educational institutions and funding agencies (Boykin et al., 2020; López & Cesspooch, 2019; Smith et al., 2007; Williams, 2018).

Additionally, all team leaders should foster a culture where open dialog and mutual learning are valued and normalized. An example of this from our team was the development of the UVM-JSU partnership described in Section 2. Creating time and space throughout the research process for dialog and mutual learning is especially important when operationalizing values of diversity and equity. In addition to fostering awareness among white researchers, dialog and mutual learning will ideally lead to the co-creation of value-driven team goals, expectations, and norms. Co-creation not only brings all perspectives into the project culture but also promotes adoption of the expectations and norms by more team members. In the absence of this public process, however, some team members may see these conversations as a distraction from research progress and avoid authentic engagement. The cultivation of psychological safety, or the communal sense that the team is a safe environment for interpersonal risk taking (Edmondson, 1999), is an important aspect in this context, but what constitutes a safe space depends on identity. For example, for BIPOC team members it can be painful to witness the slow learning of white colleagues. Some white team members may be reluctant to engage if they fear being criticized for their viewpoints or lack of knowledge and skills, both hindering the goal of truly fostering diversity of perspectives to strengthen CZ science and education. Therefore, leaders should take actions to foster psychological safety such as minimizing power differences among team members, facilitating and encouraging contributions from all team members, and engaging in effective coaching (Kozlowski & Bell, 2019) while keeping identities in mind.

Avoiding additional trauma for BIPOC participants during this process is especially important. One facilitation strategy that may minimize additional trauma is to have initial conversations about identities in separate groups that do not require BIPOC team members to educate white peers (Dennis, 2020). This approach has been used successfully in organizations and groups such as Black Lives Matter (BLM; e.g., https://www.blmcollective.org).

The literature offers a wide variety of leadership resources, from management strategies and vision development to an introspective assessment of one's own patterns, including around identity (DiAngelo, 2018; Kendi, 2019; Oluo, 2019). We collectively suggest that white leaders take part in workshops on leadership and diversity, read about the topic, and find a network of other leaders to learn from when challenges around "race" and racism arise. Importantly, funders of CZ science should require leadership training in team science and encourage CZ team science leaders to seek training in the absence of a mandate. Further, to incentivize all leaders regardless of identity to work toward increasing diversity in the geosciences, departments should incentivize this work by incorporating efforts into annual performance reviews, tenure, and promotion criteria (Ormand et al., 2022). To improve gender equity, institutions and teams may also consider formal allyship training for male researchers and educators (Nash et al., 2021). Funding institutions should incentivize diversity and equity work by elevating the importance of DEI criteria when evaluating research proposals.

3.2. Characteristics of Team Members and Team Composition in CZ Science and Education

3.2.1. Diversity

CZ science requires cross-disciplinary teams to solve complex, societally relevant issues. However, creating impactful and high functioning teams that can tackle complex issues requires consideration of diversity beyond discipline (Cheruvelil et al., 2014; Galinsky et al., 2015; Gibbs et al., 2019).

Diversity can include traditional demographic traits such as "race," gender, and age, and less-visible factors such as career stage, skills, abilities, and mode of interaction. Teams that diversify across a range of these factors can produce more high impact research and education outcomes for two primary reasons (Cheruvelil et al., 2014; Yang et al., 2022). First, diverse teams have access to a greater variety of perspectives and approaches when solving problems. Second, diversity promotes team and cognitive processing that result in creativity, innovation, and more effective problem solving (Galinsky et al., 2015; Gibbs et al., 2019). Importantly, CZ teams designed with multidimensional diversity in mind can promote a CZ science and education team that more equitably reflects all communities they seek to serve. Yet, diversity can have disruptive effects on team processes if teams fail to embrace and integrate differences in beliefs, attitudes, and preferences, and instead move toward similar-ity (Gibbs et al., 2019; Kozlowski & Bell, 2019; Mannix & Neale, 2005). Therefore, group processes must be thoughtfully managed, for example, through effective leadership, to reduce conflict and misunderstanding, and instead leverage differences to increase the accuracy and quality of judgment and decision-making in teams (Hall et al., 2019; Kozlowski & Bell, 2019; Nielsen et al., 2018).

There are many existing resources that can help institutions and teams increase and maintain diversity at all levels. For example, Callahan et al. (2017) and Baber et al. (2010) provide recommendations and frameworks for recruiting and retaining BIPOC students. Martinez-Cola (2020) offers advice for BIPOC students with white mentors. Additionally, Ormand et al. (2022) offer advice for making academic departments more diverse, equita-ble, and inclusive. There are also several websites that offer recommendations for improving diversity, equity, and inclusion in the geosciences. These include the NSF-funded Unlearning Racism in Geoscience project (URGE; https://urgeoscience.org/) and the ADVANCE-Geo Partnership (https://serc.carleton.edu/advancegeo/resources/index.html).

3.2.2. Team Roles

Another dimension of team diversity beyond demographic traits is the mode(s) of interaction that a member adopts within the team. Common modes have been described as "specialist," "generalist," "broker," and "outward engager" (Figure 2; Cheruvelil et al., 2014). Specialists are individuals who primarily have disci-plinary knowledge and skills in one or two areas (Figure 2a). Conversely, generalists tend to have knowledge and skills in multiple disciplines (Figure 2b). While some individuals' primary contribution to a team can be discipline-focused, both specialists and generalists can also serve as either brokers or outward engagers. Brokers promote the cross-fertilization of ideas by bridging team members and innovative ideas within the team

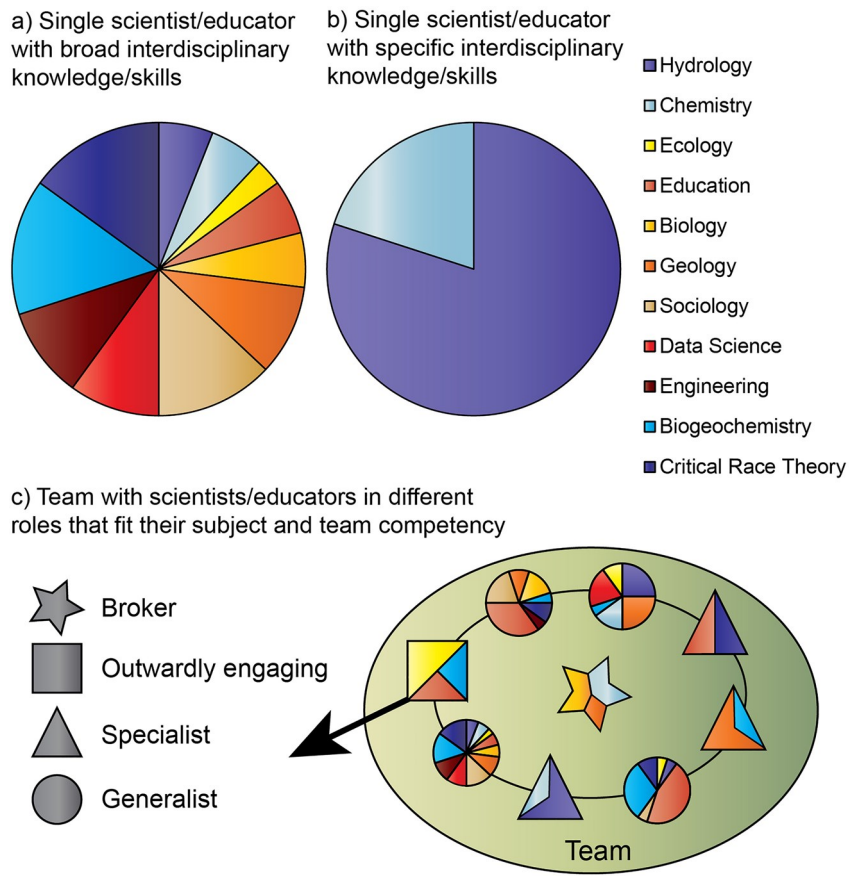

Figure 2. Schematic representation of disciplines that scientists and educators might engage with and how these overlap with team roles. (a) An example of a highly interdisciplinary scientist or educator who engages with several disciplines regularly and (b) an example of a scientist or educator who primarily focuses on two disciplines. (c) Interdisciplinary science is science that is conducted by teams and requires disciplinary breadth (scientist/educator featured in (a)) and depth (scientist/educator featured in (b)) and the ability to bridge between these approaches (broker) and engage the community (outward engagers) (modified from Cheruvelil et al., 2014, with permission).

(Cheruvelil et al., 2014; Hall et al., 2018). Outward engagers connect teams to other teams, bringing new ideas and potential new members to their team.

It is especially relevant to consider these modes of interaction for CZ science conducted in cross-disciplinary teams. When designed using a team-based approach, cross-disciplinary CZ research and education initiatives reduce the need for any single scholar to possess expert knowledge in all relevant disciplines (Scientist in Figure 2a). Instead, teams are designed with multidimensional diversity in mind, which values disciplinary depth and breadth and interpersonal skills (social sensitivity and emotional engagement). Further, modes of interaction that promote team cohesion and bridge knowledge or approaches are prioritized and valued in addition to the disciplinary knowledge required for the specific project. While it is best to design a team with these criteria in mind, it is a powerful exercise to clarify roles post-hoc as well. For example, in our project, all leaders discussed whether they were natural brokers and/or outward engagers or thought of themselves as more of a generalist or a specialist (Cheruvelil et al., 2014). This discussion served as a thought-provoking self-interrogation tool and reminded the project leaders that diversity in both discipline and social skills was important for team success. Furthermore, this exercise moved the team a step closer to understanding and appreciating everybody's contribution despite differences in approaches.

This approach invites team members to bring all of their skill sets to the table and promotes a more inclusive model of who can be a CZ scientist or educator, which is ultimately more aligned with our team's values (Figure 1). Specifically, we contend that there are multiple ways of contributing to science and there are many ways of being a scientist. Embracing these team science values in CZ teams can help us move away from the monolithic idea

of a CZ scientist as a white male who does science by himself with a very specialized knowledge base (Jimenez et al., 2019). In turn, individuals who have historically been excluded from the geosciences may begin to envision themselves as a scientist or educator (Walls, 2012). As such, graduate training programs in geosciences should design curricula that build knowledge and skills in cross-disciplinary team science and disciplinary research (Wallen et al., 2019). We highlight the disciplinary research skills here to emphasize that disciplinary knowledge is necessary and valued, but also because evaluation criteria for jobs and funding opportunities for early career scientists still frequently reward qualities of the specialized expert (Vogel et al., 2019).

3.3. Team Processes

There are many team processes that should be considered and discussed within each team (Cozzens, 2019; NRC, 2015). Here, we discuss several processes that have been important in our journey to centering and upholding our team values, especially as they promote equity among demographics and less-visible elements of team diversity.

3.3.1. Meetings

Many key team processes occur during formal meetings. These processes include establishing group norms, relationship building, idea generation, decision-making, and having authentic dialog about team values. As such, meetings are critical to building and maintaining team culture and are the cornerstone to centering and uphold-ing team values (Graef et al., 2021). However, when conducted poorly, meetings can damage team culture and limit teams from integrating and embracing member diversity. Reflecting on our present and past experiences in team meetings, team leadership and composition were important elements of general meeting effectiveness. Further, meeting practices, such as advanced preparation and effective management of interpersonal dynamics, also increase meeting satisfaction and productivity.

In an attempt to make our meetings more useful, fulfilling, and psychologically safe, we use a few preparation and process norms to strengthen the bonds that promote collaboration and cooperation in a diverse, cross-disciplinary team (Cheruvelil et al., 2014; Nielsen et al., 2018). For example, we encourage meeting facilitators to circulate draft agendas at least 24 hr prior to the meetings. This practice helps ensure meetings are goal-oriented, gives all attendees a chance to provide feedback on or add to meeting goals, and allows team members to prepare in advance. We also intentionally spend time and energy on building relationships and have used several approaches to do this. One example from a meeting in our education team was sharing our education story or drawing our life-path. More simple exercises include spending a few minutes sharing responses to a prompt, such as "what do you wish others understood about you?," a question the actor and science communicator Alan Alda uses in his podcasts (Alda, 2018-present). These check-ins served as points of connection during times in the pandemic when no one could travel or meet in person.

To manage interpersonal dynamics during meetings, process norms or community agreements are very helpful and should be developed collaboratively by the team (see the National Equity Project https://www.nationalequityproject.org for resources). Our norms encourage all attendees to: (a) be as present as they can, (b) speak more if they are typically quiet, or speak less if they often dominate conversation, (c) give themselves permission to contribute ideas or questions even if they are half-formed and/or will not be stated eloquently (be "raggedy"), (d) assume that others have good intentions and attend to your impacts if you offend someone, and (e) listen to understand what is being said rather than to respond. While the meeting facilitator is charged with enforcing these norms and managing interpersonal dynamics, it is important for individuals to build self-awareness around effective communication. This is especially important because group communication quality, such as evenness of contributions among individuals, the nature of body language by all members, and voice tone, are all more important for predicting team productivity than the content of communication (Pentland, 2012). For example, when we conducted a teamwork exercise focused on understanding how constructive (e.g., cooperating, clarifying, risk taking) and destructive group behaviors (e.g., dominating, digressing, withdrawing; see Cheruvelil et al., 2014 Web Supplement 3 for team exercise) contribute to meeting success, some old habits were revealed. In some instances, UVM faculty were not engaging in enough "risk taking" and that some engaged in "digressing," behaviors that hinder group progress that we now address. Fortunately, this exercise also resulted in a productive discussion around "withdrawing" (listed under destructive behaviors), because some team members pointed out that what might be interpreted as withdrawing could be simply a reflection of power dynamics and a restricted

view on what a contribution constitutes. As a result, we offer multiple ways of contributing including chat functions, breakout groups, and anonymous options online.

3.3.2. Developing Self- and Team-Awareness of Values

White researchers, like many on the UVM faculty, can move through an entire career, starting with a graduate program, postdoctoral training, and the tenure track without ever having to interrogate their own identity—not because their identity does not matter, but because whiteness has been made the norm and because white scientists benefit from their whiteness. The power and privilege of this group increases the probability for persis-tent blind spots, that is, the inability to recognize the impact of biases and limitations on one's own judgment, behavior, and decisions (Pronin et al., 2002). One helpful concept is the *staircase model* in the development of intercultural competencies. This model was originally developed for communication (e.g., Ting-Toomey & Dorjee, 2015), but may be helpful in any situation that requires acknowledgment of realities that are outside our awareness. In this staircase model, we might begin with an unconsciously incompetent stage and remain there as long as nothing prompts us to rethink our implicit assumptions. The journey to the stairs of consciously competent or even unconsciously competent is via the (possibly emotionally difficult) stair of consciously incompetent. A lot of humility and learning happens in this stage, and it is important that the learner does not enlist folks with identities that are harmed by having to witness the (often slow) learning progress for support. Helms (1990) and Tatum (1992) outline the steps of "racial" identity development, which is a helpful concept to consider in this context and can help generate self-awareness.

3.3.3. Co-Authorship

Managing co-authorship is an important aspect of collaboration in diverse teams and is an especially important process for upholding our team values. Writing multi-author manuscripts efficiently can be challenging because distributed tasks make holding co-authors accountable and soliciting intellectual contributions and input from all authors difficult and time-consuming (DeHart, 2017). Further, managing co-authorship can be challenging in large, cross-disciplinary teams where members each have their own authorship culture and expectations. The work you are reading now is an example of such a publication, where several disciplines, perspectives, cultures, and experiences converge. To help alleviate potential conflicts that arise in collaborative manuscript development, we suggest many of the strategies introduced by Oliver et al. (2018). These include discussing authorship early and often, collaboratively writing an authorship policy, openly announcing manuscript ideas early in the process, clarifying expectations for authorship, and documenting authorship contributions. All these aspects directly serve our values, because we are being asked to consider "who" is contributing and "how" we will work, that is, diversity, equity, and community are incorporated in our co-authorship agreements. This practice equally serves efficiency, for example, by defining how to respond when the lead authors do not move manuscript tasks forward. In this case, a strategy can be to temporarily pass on the role of the manuscript coordinator until the leads have the capacity to assume this role again. Adoption of this approach is much more likely when team leads do not have to fear loss of authorship when temporarily sharing or changing roles (Oliver et al., 2018). In our work we found the development of co-authorship agreements an important process; however, we realize that putting these agreements into practice takes intention and time. For example, by forgetting to fill out the contribution matrix ahead of time, we did not follow our own agreement for this publication in this important aspect.

4. Final Thoughts: Connecting Values, Team Science, and Performance

A large body of research has shown that effectively collaborative, diverse teams have performance levels that significantly exceed that of individuals. While the level of science performance is traditionally measured in citation metrics for publications or the number of grants generated, an approach that could better serve science, education, and society would be holistic indicators of impact. Examples of alternative indicators include the number of students trained in collaborative team science approaches, the community members engaged, and the strength of collaborative relationships established. Ultimately, "impact" can be defined and interpreted in many ways, some of which cannot be easily quantified but are nonetheless critical outcomes from team science approaches. Evaluating performance in the context of traditional metrics must go hand-in-hand with our values in order to have a high (and positive) impact (Figure 3). In this view, "high impact" science and education is only possible when teams are diverse, equitable, and community-oriented, and when individual and team skills are developed to harness the power of these multiple perspectives, experiences, and approaches. In turn, the zero-sum belief

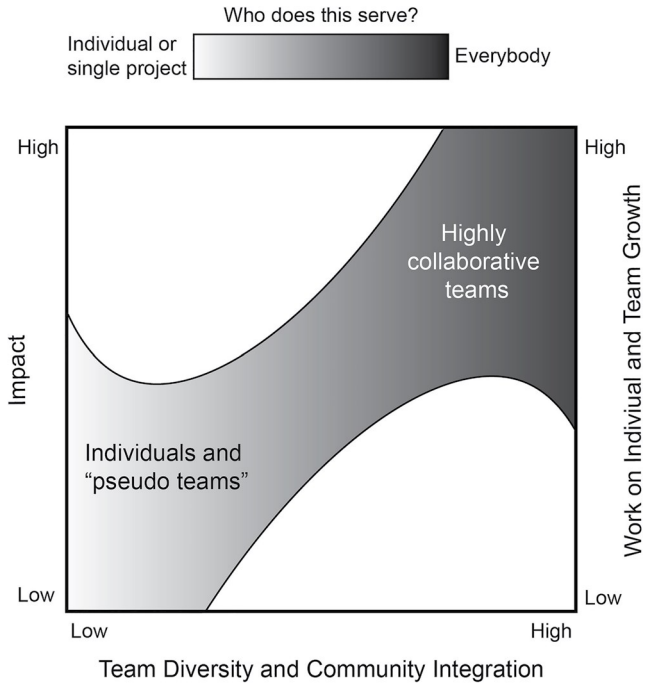

Figure 3. Schematic representation of the connection between diversity, community, work on individual and team growth, and resulting impact (modified from Cheruvelil et al., 2014, with permission). "Pseudo teams" refers to teams that lack trust and exhibit high degrees of ambiguity around objectives and responsibility, resulting in silo-work instead of teamwork.

that investing resources (time, energy, headspace, and money) in building such teams would slow down research progress or impact is flawed, because research and education cannot have impact when only a few benefit. Growing interdisciplinary fields such as CZ science have the potential to make large contributions to science and education that benefit all by re-defining impact based on values and by offering more holistic metrics for success.

5. Positionality Statements

We acknowledge our varied positionality with respect of privilege and power in the order of authors: Perdrial is the lead PI of the project and identifies as a middle-class and educated white woman from Europe who is living in the US by choice since 2008. Her upbringing outside of the U.S. and her significant power and privilege comes with blind spots that might influence this work. Kincaid is a postdoctoral researcher on the project. He is a first-generation college student who identifies as a cis-gender, gay, white male from the U.S. His academic training was done in primarily white programs in primarily white U.S. institutions. He acknowledges that his background and privilege create unconscious biases that may impact his diversity, equity, and inclusion work. Wheaton is a sub-awardee on the project and identifies as an African American woman, first-generation college student, from a working-class family in Mississippi, who has made a professional commitment to serving students at Historically Black Colleges and Universities. Her experiences facing educational roadblocks and benefiting from initiatives designed to increase diversity in higher education are both key drivers of her passion for researching and advocating for educational equity and broadening participation efforts—especially in STEM education. Seybold is a co-PI on the project and identifies as an early-career, middle-class, educated white woman from the U.S. working in a predominantly white, male field (geosciences). Stewart is a graduate student researcher on the project who identifies as a middle-class, multiethnic American woman who benefitted from STEM diversity and inclusion efforts. Her perspective in this work is influenced by her career level, education, experiences in academia, and identity-driven privileges. Walls' experiences as electrical engineer, middle school science teacher, resident of a city routinely ranked as one of the most "racially" hyper-segregated in the U.S., tenured professor at a predominantly ethnic European university, parent and grandparent of multiethnic children and grandchildren, and having grown up an ethnic African male in America, have all in their own way helped forge an intimate bond between "race" and him. These experiences have shaped his beliefs and worldview and conditioned his skepticism as a researcher; piqued his curiosity about the origins of educational inequities that befall ethnic African and other children of color; and finally, prepared him to challenge "commonly held beliefs" while also seeking research supported solutions on their behalf. Blouin is a middle-class white man who has lived in Burlington, VT since 2013. He grew up in a wealthy, largely white community and school system; his teaching career has included work with students from a variety of economic classes and racial identities, though in his current role as a senior lecturer at UVM his colleagues and students are predominantly white and middle- or upper-class. While he engages frequently with issues of equity, his understanding comes largely from relationships, reading, and research rather than lived experience of bias or discrimination. Toolin is a co-PI on the project and identifies as a middle-class white woman from New York City. Her working-class roots and experience living, teaching, and researching in a large urban context have greatly informed her evolving perspectives and practices pertaining to DEIJ. Chorover's identity as a white man has facilitated his attainment of his current influential position as professor and department head at University of Arizona. Lewis is a co-PI on the project and identifies as a middle-class African American woman from a mixed heritage in a southern state. She is a fourth-generation educator whose life experiences shape her perspectives and guide her desires for assisting the field of education to obtain a more diverse pool of researchers.

Conflict of Interest

The authors declare no conflicts of interest relevant to this study.

Data Availability Statement

The authors state that there is no data to declare.

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