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POSITION PAPER

Broadening participation in environmental data science: Insights from practitioners

Caitlin R. Fong[1,2], Carmen Galaz García[1], Emman Abbasi[3], Nick Gubbins[4] and Zeynab Jouzi[5]

[1]National Center for Ecological Analysis and Synthesis, University of California, Santa Barbara, CA 93101, USA
[2]Department of Ecology, Evolution, and Marine Biology, University of California, Santa Barbara, CA 93101, USA
[3]Department of Biology, University of Pennsylvania, 433 S University Ave, Philadelphia, PA 19104, USA
[4]Colorado State University, Fort Collins, CO 80521, USA
[5]Action Research Collaborative (ARC), Cornell University, New York 14853, USA
Corresponding author: C. R. Fong; Email: fong@nceas.ucsb.edu

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Abstract

Environmental data science (EDS) is a nascent STEM sub-discipline where we have the opportunity to shape the culture, to work to create an environment that welcomes broad participation, and to build a culture of inclusivity. Like many STEM disciplines, some may be excluded from participating in EDS due to historical legacies, systemic barriers, and social prejudices that create unequal opportunities and access. To better understand barriers to participation, and to identify solutions and priorities, we conducted a survey of the participants of the first Environmental Data Science Summit. We identified three barriers to participation that matched with three solutions and priorities for the field. The most commonly identified barrier was an unsupportive work environment for minorities and a male-dominated culture; creating a supportive community and work environment, particularly for minorities, was identified as both a solution and a priority for broadening participation in EDS. The second most commonly identified barrier pertained to training and maintaining relevance— specifically, late or informal training experiences and time constraints limiting time to upskill. The solution and priority proposed included access to good mentors and teachers, open data and educational materials, and increased applicability of projects. Finally, the third most commonly identified barrier, solution, and priority relate to financial concerns and the funding landscape, with both the solution and priority identified as improving funding and salary conditions. The results of this study identify the key barrier to participation in EDS and highlight potential solutions to lower these barriers to build a more equitable future.

Impact Statement

Like in many STEM fields, historical legacies, systemic barriers, and social prejudices likely exclude some groups from participation in Environmental Data Science (EDS). A necessary first step to address under-representation and limited participation in the field is to define the scope of the problem, as well as to identify successful solutions. We surveyed participants of the first Environmental Data Science Summit to better understand participants' perceptions of barriers to participation as well as perceived solutions to broadening participation. Our results indicate the three main barriers to participation, and their solutions, pertain to culture, training, and funding. These barriers require concerted systemic change to address, and are a necessity to solve if we wish to build a more equitable field.

1. Introduction

Broadening participation and increasing inclusivity in professional spaces have increasingly become important as we reckon with exclusion stemming from social prejudices, systemic barriers, and historic legacies. Like many professions, Environmental Data Science (EDS) risks being or becoming, an exclusive and inequitable field due to these unevenly distributed barriers to participation (Berman and Bourne, 2015; Behl et al., 2021; Marin-Spiotta et al., 2023). However, the inclusion and participation of people from diverse backgrounds with diverse experiences are necessary both to ensure the profession is equitable and to ensure we harness the full human potential insight and capacity. Without full inclusion and participation in EDS, we lose out on identifying essential perspectives and connections, which are crucial to solving environmental problems (National Center for Science and Engineering Statistics, 2023). Thus, broadening participation in EDS is beneficial, and we are at a critical juncture where we, as a community, can shape the direction of our nascent field.

Narrow participation has severe consequences, with evidence in both environmental and data science disciplines. Without active efforts to include diverse perspectives and experiences, harmful communications and practices can be perpetuated. Examples include the ubiquitous use of "pioneer" and "colonizer" in ecology (Cheng et al., 2023) and "master" and "slave" in computer science (which has recently been dis-adopted (Landau, 2020). Harmful outcomes of data application include racist hiring (Peyush, 2022), sentencing (Brackey, 2019; Mesa, 2021), and policing (Angwin et al., 2016) applications. Because these applications are trained on existing data, they inherit the racism of historical practices, resulting in an unintentional, but not inevitable, racist outcome. Notably, diverse participation in the development of terms and tools could help safeguard against these harmful outcomes and build a more inclusive future.

A necessary first step to broadening participation in EDS is identifying perceptions of barriers to participation as well as successful solutions. For this Position piece, we survey practicing environmental data scientists to quantitatively and qualitatively describe experiences in the field, as well as to elucidate commonalities and differences in experience across individuals. Specifically, we seek to identify common barriers to participation in EDS as well as provide solutions and suggestions for broadening participation in the future.

2. Methods

Between March and February of 2023, we surveyed the participants of the inaugural Environmental Data Science (EDS) Summit. All participants were engaged professionally in solving environmental science questions using data science as a tool, and all participants were invited to respond to the survey (excluding those in the working group, n = 97). The survey aimed to identify common barriers to participation in EDS and general solutions and priorities for broadening participation in the future. The survey was performed under Exempt UCSB IRB protocol #10-23-0116 to CRF.

Survey questions covered basic questions including demographic information about age, gender, identity, sexual orientation, socioeconomic background, and geographical location. This demographic information was used to contextualize responses to additional questions. We also asked questions about professional experience in EDS, educational background, sector of employment, annual salary, and the status of the respondent's position in the organization (full-time/part-time and contract/permanent). Finally, we asked a series of questions aimed at understanding how likely participants were to stay in EDS, what facilitated or posed a barrier to their participation in EDS, and what individuals believed should be the priorities for increasing participation in EDS. These open-ended questions provided us with a more complete qualitative picture of the participants' experiences and opinions based on their unique experiences on retention and participation in the EDS.

Surveys were administered in the same order for each respondent, and the complete survey is available in the Supplementary Material. We report frequency of responses and emergent themes; replication was too low to compare responses across demographic groups.

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3. Results

Overall, we had 34 of 97 participants respond to our survey. Of note, not all participants answered every question. Due to the limited sample sizes, completely crossed statistical designs were not possible in many cases. All of our participants live and work in the United States.

3.1. Demographics of survey participants

The majority of participants were between the ages of 31–40 (n = 16), followed by equal representation of individuals aged 21–30 and 41–50 (n = 7 for each). The remainder of participants were 51–60 (n = 2) or chose not to respond (n = 2). Approximately 75% of our respondents identified as women while 15% identified as men. One participant identified as non-binary, while two chose not to respond. Half of our respondents identified as heterosexual, and half identified as queer. The majority of our participants reported no disabilities (n = 26); five reported disabilities included cognitive or other disabilities while the remaining three chose to not disclose.

The majority of participants identified as white (~70%); our survey included 2 Black people, 2 Hispanic people, 1 Asian person, and 1 mixed person; 3 individuals preferred to not disclose. Notably, all but one woman identified as white while no male respondents identified as white.

For all respondents, at least one parent had attended college. For the majority, parents had earned PhDs (n = 10), Masters (n = 10), Bachelors (n = 7), or Professional (n = 6) degrees. Few respondents (<20%) had qualified for free lunch programs while in K-12.

3.2. Professional experience in EDS

All of our respondents had achieved degrees in higher education, with bias toward doctoral (n = 20), then masters (n = 10), with only a few bachelor (n = 3) and professional (n = 1) degrees. A majority of our respondents had degrees in life sciences, including ecology (n = 11), environmental science (n = 10), biology(n = 3); a few respondents had degrees in geography (n = 3). We had a single respondent for each of six other specialty STEM fields.

On average, respondents had 9+/− 1 years of experience in EDS. Approximately 70% of our respondents work in academia (n = 24), while the rest were relatively evenly distributed among industry (n = 4), government (n = 3), and non-government organizations (n = 3). Most respondents were employed full time, and roughly split between permanent (n = 16) and contract (n = 13) positions; a minority had part time contract jobs (n = 4).

All of our respondents were paid for their work in EDS. Pay was fairly normally distributed; most earned 50-90 k (n = 13) or 100-199 k (n = 10). A handful earned 25-49 k (n = 5), while few earned <25 k (n = 2) or more than 200 k (n = 3). Of note, the highest earners worked in academia. Job positions or titles varied, likely as a result of variation across sectors; however, our most common responses were professor (n = 13), PhD student (n = 7), and "senior scientist" (n = 4). The remaining titles appeared to be idiosyncratic.

3.3. Opinion and perspective on participation in EDS

Most respondents felt they were likely to stay in EDS in the next year; however, strength of positive response decreased with increasing time domain. In the next year, all white women responded they were very likely to stay in EDS (n = 5) while all but one non-white felt they were less likely to stay in EDS (Figure 1). In 5 and 10 years, all non-white people responded they were less likely to stay in EDS; in 10 years, all non-white people scored this question at 3 or lower. Given the lack of replication (n = 5 non-white people), statistical analyses are not sufficiently robust to compare responses across race.

We then gave respondents the opportunity to explain 1) why they answered as they did when asked how likely they were to stay in EDS, 2) what barriers, if any, they have faced in participating in EDS, 3) what has facilitated their participation in EDS, and 4) what are the most urgent priorities for broadening participation in EDS.

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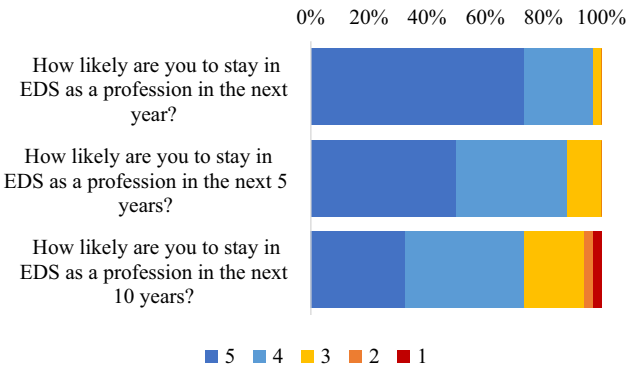

Figure 1. *5 indicates "very likely" (dark blue), while 1 means "very unlikely" (red).*

3.4. Responses to "what influenced your decision to stay in or leave EDS as a profession?"

Overall, participants' responses to staying or leaving EDS as a profession were influenced by (1) the requirements of their current or desired job, and job availability and market needs (n = 13), (2) enjoyment and personal interest (n = 9), and (3) high demand of a fast-paced field (n = 2).

The most commonly reported factor influencing perception around remaining in EDS was the requirements of their current or desired job and the ease of finding a job with data science skills and the demands of the job market (n = 13). For example, participants mentioned that: "*EDS, and data science in general, is where jobs are--it seems like a lucrative thing to pursue." and "I only see that need increasing over the next 10 years."* The next most common responses pertained to personal enjoyment and interests (n = 9). Of note, respondents acknowledged the challenges associated with staying up to date, and the pressure to constantly learn and adapt, as a reason to leave EDS (n = 2), for example, "*The pace of research or deliverables, how it's expected that you will juggle a large number of projects at once, and [the] constant difficulty I've experienced in obtaining accommodations for my disability is exhausting and discouraging, so I don't see EDS as a long-term option.*"

3.5. Responses to "what are the barriers, if any, that you have faced in participating in EDS?"

Participants identified multiple barriers to participation in EDS, including an unsupportive work environment for minorities and a male-dominant culture (n = 11), late or informal training experience (n = 11), time constraints for updating skills (n = 6), and financial concerns and funding issues in academia (n = 5).

Participants identified an unsupportive work environment for minorities as well as a male dominated culture as one of the main barriers to participation (n = 11). Responses included calling out the lack of racial and ethnic diversity in EDS, noting, "*The folks that I saw doing EDS were white, cis-hetero, men and it felt intimidating/difficult to break into*," while another participant noted that "*The field can be very patriarchal and that's very challenging.*" Participants mentioned barriers such as being the "*Only black female,*" "*Being from a marginalized and underrepresented community*", or having "*An invisible disability.*" Another barrier to participation identified by respondents is having late or informal learning experiences, including an inadequate mathematics and computer science background (n = 11), for example, stating, "*I thought (and still have thoughts) that I shouldn't pursue a career in software/programming because I am self-taught and don't have a formal background in it.*" Participants felt they did not have enough time to stay current or acquire new skills to work in EDS (n = 6). Due to the fast-moving pace of advances in data science, participants feel the need to self-teach skills, which is at odds with academic demands, such as teaching and service, and personal obligations. For example, one participant noted that "*working full-time and having family commitments, it can be challenging to find extra time to teach myself new skills.*" Finally, financial concerns and a lack of funding for EDS in academia are often noted barriers to participation (n = 5). Participants noted that the lack of funding hindered their ability to conduct EDS research; one respondent mentioned "*Finding salary support for very time-consuming computational work through environmental*

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science." Low academic salaries also disincentivize participation in the field, with one participant stating that "*EDS professionals in academia are paid less than their counterparts in industry.*"

3.6. Responses to "what has facilitated your participation in EDS?"

Overall, the participants emphasized the critical role of a supportive community (n = 12), mentors and teachers (n = 9), open access data and educational materials (n = 4), and funding opportunities (n = 3). A key theme that emerged was the importance of a supportive community and the value of being part of a network of like-minded individuals who share similar interests and goals. This community provided a platform for collaboration, knowledge-sharing, and peer support, which greatly contributed to engagement in EDS. In particular, one participant noted "*I have always found environmental science spaces to be more welcoming than more basic sciences (physics, mathematics, computer science,* etc.*).*" Another factor facilitating participation was the role of mentors and teachers (n = 9), positively describing "*A patient mentor… is basically solely responsible for my love of EDS and my ability, confidence, and enjoyment of coding and data science.*" The availability of open access data and educational materials emerged as another significant facilitator (n = 4) as well as funding (n = 3).

3.7. Responses to "in your opinion, what are the most urgent priorities for broadening participation in EDS?"

Respondents identified four key priorities for broadening participation in EDS, including developing supportive work environments, particularly for under-represented people in EDS (n = 12), improving funding and salary conditions (n = 10), improving access to EDS education (n = 7), and engaging diverse communities through EDS applications to increase the visibility of this field (n = 4).

Creating welcoming and supportive work environments, particularly for under-represented people, was identified as one of the most urgent priorities for broadening participation in EDS (n = 12). Suggestions included supporting and mentoring under-represented and diverse participants, offering training on creating inclusive and respectful workspaces, and constructing more horizontal and open communities. Easing the financial concerns of EDS participants was identified as urgently needed to broaden recruitment and retention (n = 10). Priorities include increasing academic salaries—seen as low compared to what participants perceive someone with EDS skills could earn in industry—providing fellowships for early career scholars and students at all education levels, and funding for smaller research projects. Participants mentioned that "*Salaries need to be higher. Make the profession worth it for people who are coming from lower income backgrounds.*" Another priority is increasing access to EDS education (n = 7). Respondents emphasized the importance of beginner-friendly resources that taught coding by focusing on environmental science and real-world applications. For example, one participant suggested, "*Take something like Software and Data Carpentry and build it out to support more technical skills in EDS.*" Participants also highlighted the need for equitable access to EDS education at all levels, from pre-college to informal continuing education for researchers, with one respondent noting the importance of "*Introducing EDS to students below the higher education level and formal training in schools.*" Finally, boosting the visibility of EDS through real-world applications and community engagement was identified as a pathway to broaden participation (n = 4). Concrete actions proposed by respondents include increasing the visibility of EDS as a career, particularly in previously unreached communities, making sure EDS studies are implemented to solve concrete challenges, and, in the words of a respondent, "*Ensuring that EDS is relevant/useful to a wide range of communities.*"

4. Discussion

This study aims to identify the barriers and opportunities to diversify the Environmental Data Science field by collecting opinions and insights from the participants of the first Environmental Data Science Summit in Santa Barbara that had the focus on the theme of Harnessing Diversity in Environmental Data Science. Our

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survey results indicate the three main barriers to participation, and their corresponding solutions, pertain to culture, training, and funding. All three of these barriers require concerted systemic change to address, and are a necessity to solve if we wish to lower barriers to participation and build a more equitable field.

The most commonly identified barrier to participation in EDS was an unsupportive work environment for minorities and a male-dominated culture. Concurrently, participants identified creating a supportive community and work environment, particularly for minorities, as both a solution and a priority for broadening participation in EDS. Thus, our participants indicate EDS may already be an exclusive and inequitable field, like much of STEM, specially the computing and engineering fields (Boucher et al., 2017), which is unsurprising given the social prejudices, systemic barriers, and historical legacies that influence access to higher education (Berman and Bourne et al., 2015; Behl et al., 2021; Marin-Spiotta et al., 2023) and hiring practices (Peyush, 2022), both of which serve as filters to employment. Changing the work environment to support minority participation and inclusion requires a culture shift, which is notoriously difficult. In many cases, necessarily open and frank conversations place minority participants in positions of vulnerability and are difficult for white participants, who often find it difficult to contribute (Gonzales et al., 2021). A handful of opinion pieces have been published to address culture in data science (e.g., Gaynor et al., 2022; Geiger et al., 2019; Santa Barbara Charter: Broadening Participation in Environmental Data Science, 2023) and within organizations more broadly (El-Amin, 2021), with recommendations that include changes in advancement evaluation, codes of conduct, hiring of diverse cohorts, long-term commitment to institutional change, and the importance of formal roles within organizations (e.g., a Diversity Officer position, whose role is to eliminate barriers to participation and proactively shift organizational culture). While the specific actions that will have the greatest effect likely vary across organizations, our survey demonstrates that practicing environmental data scientists are dissatisfied with the status quo, and a culture shift should be a priority for those in leadership positions to broaden participation in EDS.

The second most commonly identified barrier, solution, and priority pertained to training and relevance. Our participants identified the barrier to participation as late or informal training experiences and time constraints around updating skills, the solutions as access to good mentors and teachers and open access data and educational materials, and the priority as improved access to EDS education and applicability as a priority for broadening participation. Our participants often felt they lacked formal training in their job before starting, and elevated the availability of training programs as a factor that facilitated their participation. There are a variety of online training opportunities, some of which are free, that individuals could leverage to increase and update their skill sets (including: NCEAS learning hub; Data Science for Ecologists and Environmental Scientists; The Carpentries; Openscapes). However, this availability does not change the time constraint for employees. Here, organizations could include time blocks in job descriptions and expectations to "skill up." In many cases, the guidance of a skilled instructor and access to good mentors can reduce barriers to participation. Engaging and effective teaching practices increase learning outcomes, particularly for capable but underprepared trainees and minorities (Haak et al., 2011). The importance of mentors, particularly with shared experience and background, has been identified as particularly important for women and minorities in STEM (Kricorian et al., 2020) and helps shape identity and sense of belonging (Atkins et al., 2020). Our participants identified improving access to EDS education as a priority for broadening participation; this priority is likely to be achieved through undergraduate and graduate institutions. Like for much of STEM, this will require recruitment and retention of diverse trainees in academic institutions as well as implementation of effective pedagogy (Haak et al., 2011; Toven-Lindsey et al., 2015; Estrada et al., 2016, 2018; Burke et al., 2020; Markle et al., 2022). Finally, our participants identified increasing applicability of EDS to diverse communities as a mechanism to recruiting diverse participants into the field. Collectively, addressing barriers to EDS related to training will involve (1) sufficient access, (2) built-in time for advancing skills on the job, (3) availability of qualified instructors and mentors, (4) changes in academic institutions, and (5) increased real world relevance of EDS applications.

The third most commonly identified barrier, solution, and priority relate to financial concerns and the funding landscape in EDS, with both the solution and priority identified as improving funding and salary conditions. The majority of our respondents are currently employed in academia, which likely strongly

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influenced this response. Salaries are simply higher in industry across STEM fields in the US, Canada, and Europe and academics have become increasingly dissatisfied with stagnant wages (Woolston, 2021). In contrast, data science is rapidly growing in the private sector, and offers highly competitive salaries. Indeed, industry surveys suggest a pay gap of 30% (Madhusoodanan, 2014). We posit the lure of higher salary may be particularly high for those who grew up poor, reducing retention in academia and boosting the appeal of industry, which may broaden participation in EDS, albeit outside of the academy. Thus, for academia to compete with industry and be more accessible and equitable, institutions will need to offer competitive salaries, starting with the lowest wage earners.

5. Conclusion

Systemic change and long-term investment in strategies to diversify Environmental Data Science are necessary and require proactive efforts and strategies, like those identified here and in other pieces. Shifts in culture, training, and pay will require vocal and unequivocal support from those in power and those who are able in order to build a more equitable and inclusive field. In the United States, this may be a particularly precipitous moment, as long-held measures to diversify higher education have been repealed (e.g., the 2023 SFFA vs Harvard decision), potentially rolling back decades of progress. We acknowledge the political climate may limit the capacity for those in positional power to take an active role in broadening participation, as these actions may result in severe disciplinary action or loss of employment. Of particular note, recent legislation in Florida aims to curtain funding to DEI efforts and strip tenure protections, effectively disincentivizing advocation and even punishing faculty who act. However, there is power in numbers, and we encourage all who are able to lend support, to consider endorsing The Santa Barbara Charter: Broadening Participation in Environmental Data Science, to carry out the recommendations in the charter and in this Perspective as they are able.

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