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An early career perspective on the opportunities and challenges of team science

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The value and promise of team science have been increasingly recognized in many fields.[1-5] Team science is broadly defined as collaborative research conducted by more than one investigator (typically 2-10) in an interdependent manner[1], and larger groups are usually involved in big team science. Interdisciplinary and team-based research has become an imperative component in environmental science and engineering, given the nature of the grand challenges that our community is facing in the 21st century.[6] Research on existing team science projects have highlighted that participation of early career researchers can bring in diverse and "fresh" perspectives,[3] and the National academies report on environmental engineering for the 21st century also calls for engagement of early career scholars for successful interdisciplinary collaboration.[6] As new trends such as team science emerge, it is important to understand how issues related to career advancement may arise. In this viewpoint, we share a perspective on how a concerted effort can be made by early career scholars and the broader community to address these challenges and to embrace the opportunities of team science.

In recognition of the importance and growing role of team science, various institutes have started to incorporate collaborative research experiences in the trainings of PhDs, postdocs, and even undergraduate students.[7-9] Engagement in team science in this early stage is valuable for long-term career development.[3, 4, 9-11] For example, the authors have benefited from exposure to team science as a graduate student or postdoc researcher. Such experience has helped us start a professional network that includes scholars from multiple institutes and backgrounds. We recognize that such interactions and connections typically involve in-depth communication and collaborative activities, and are thus more meaningful than professional networking in occasions such as conferences. This network is also likely to help provide letters that are critical for the promotion and tenure processes. In addition, engaging in team science has also provided us with increased access to facilities/instruments, data and tools, expertise, and other resources that are necessary to strengthen and broaden our core research programs. Furthermore, soft skills that we acquire in team-based

research projects, including interpersonal skills and effective communication,[12] have better prepared us for initiating and establishing new collaborations.

These benefits, however, are not to be taken for granted as teams may form and operate in inequitable ways. Successful team science projects require not only the inclusion of diverse knowledge, perspectives and research methods,[1] but also an inclusive work environment where all members are empowered to participate in decision-making and communication. In particular, for early engagement in team science to be a positive experience, support from mentors and senior colleagues is critical.[12-14] In our experiences, in addition to sharing professional networks, providing substantive feedback, and offering advice on career development, mentors and senior colleagues can play an important role in promoting the inclusiveness of the team by acting as upstanding allies and providing assistance in conflict resolution. Institutional support can also be valuable. Training and workshops on team science can introduce the participants to the science behind team science, and thus provide the context and tools for practicing team science. The Center for Research, Excellence and Diversity in Team Science (CREDITS) co-sponsored by NSF and several institutes is an example of such effort. All of these actions foster a team culture where members are safe to participate, take risks, and get the support of others through troubleshooting and failure.[15]

Even with the continued efforts in encouraging and promoting team science just described, researchers at the stage of junior faculty in universities or junior scientists in research laboratories, who are on a tenure clock, often struggle to engage in team science.[14] This is partly because our current evaluation system of research performance has not fully adapted to the emergence of team science. In our current evaluation system, journal publications are the primary currency and independent research can easily be gauged by the number of first-author, single-author, or corresponding-author publications. Even in national laboratories that champion team science, the performance review process tends to put overly high weight on first author publications and fails to have guidelines to systematically evaluate contributions that did not translate to first-author publications. In addition, the norms of authorship can be opaque or vary significantly among groups and fields, and practices such as honorary authorship and ghost authorship may affect early career researchers disproportionately.[16, 17] Credit attribution is also likely to be deferential in presence of authors with more established status. Given our current evaluation systems, some other traits of team science can also become more limiting for early career researchers. For example, the upfront time investment in team projects can be large, especially when forming/joining a new team, and the turnover of publications typically takes longer.[9] In light of these challenges, our mentors, out of genuine care, tend to advise us to avoid team science. This is a practical

advice that would trade long-term benefits of team science for higher success rate in the short timeframe.

For early career researchers to be integrated into team science and benefit from it, it is important to strategize our involvement in team science. Based on our experiences, the following actions can help us achieve this.

- Evaluate our own research portfolio, identify core strengths and research directions for which the marginal returns of team science are high.
- Communicate the expectations and evaluation metrics with the home institute early (e.g., during offer negotiation) and frequently when planning out the balance between single PI project and collaborative projects.
- Prioritize collaborative projects in which overlap of research expertise among PIs is minimized, which could ease the delineation of contributions at a later stage. Admittedly, effective communication among team members could be more challenging in this case, which makes team dynamics even more important.
- Be aware of team dynamics early on. It is important to identify mentors (including both seniors and peers) and potential sponsors within the team, and evaluate potential time sinks of having to deal with difficult people at an early stage. We also recommend open and early communications of individual research and career expectations and needs within the team.
- Be mindful about how our decision regarding team science participation could affect students and other supervisees, and follow the mentoring practices recommended.

To harness the full potential of team science in advancing science and technologies in the long run, it is also imperative for funding agencies, professional societies, institutions and journals to make a joint effort to incentivize active engagement of early career scholars. Some actions that we think can be helpful include:

- Disperse studies of team science and best practices at various platforms to enhance the overall literacy of the entire community on team science. This can have a far-reaching effect on tenure prospects and our evaluation system in general, as it will help reviewers/letter writers appreciate and assess team science participation.
- Make targeted trainings on skills and challenges involved in practicing team science widely accessible. The studies of team science can inform topics of interest. For example, trust building, conflict management, effective communication and mentorship/sponsorship programs have been identified as valuable for team building.[18]
- Issue clear guidelines on the engagement of early career researchers in team science projects. This action, especially by funding agencies, can help address issues such as trading time for the opportunity to participate in team projects by early career researchers, which results in disproportionate funding levels for the proposed work-scope or time

commitment. The guidelines should recognize that early career scientists and faculties may need to hire and train new staff and students, and such consideration in the flow of tasks and budget should not be penalized.

- Provide clear guidelines on authorship. Journals, like ES&T family of journals, have an important role to play in shaping the norms of authorship in the field. Requiring a clear statement on author contribution is an inexpensive but invaluable step. The statement will prompt early discussion of the author list and credit allocation, and can serve as an 'official' proof agreed upon by the team for any author, - regardless of the authorship order, - to make a credit claim in performance evaluations.
- Develop clear guidelines on allocating credit for research products that are not journal publications, which could include reports, codes, data, etc., as well as other activities that demonstrate scholarship such as committee service [4]. The guidelines should also include mechanisms to recognize early career researchers' leadership roles as (sub)task leads in team projects, which typically require comparable efforts as the principal investigator of single-PI projects.

Professional societies, journals, and funding agencies are in a position to take initiatives on developing guidelines and formalizing such efforts, which can then be adopted by individual institutes. National laboratories, given their high level of engagement in big team science, can also serve as the forefront to develop, adopt, demonstrate, and promote team science practices. While not explicitly included in the recommendations above, it goes without saying that these efforts are in alignment with our diversity, equity and inclusion values, and are synergistic with DEI practices.

Table 1. Summary of recommendations for promoting early career participation in team science

Early career scholars	Broad research community
• Identify research directions that benefit from team science the most • Early communication of expectations regarding team science participation • Prioritize collaborative projects with less expertise overlap • Early assessment of team dynamics • Support supervisees in the process	• Disperse science of team science • Targeted trainings for best practices • Clear guidelines on early career scholar participation in collaborative projects FOAs • Clear guidelines on authorship • Clear guidelines on scholarly contributions other than journal publications

In this viewpoint, we identified some opportunities and challenges of team science, especially for early career scholars. We also presented a few practical recommendations for early career scholars and the broader community (as summarized in Table 1), in order to make team science more inclusive and successful for environmental research. We expect this to be an evolving process, in which decisions and actions of the early career researchers and other stakeholders of the community are inter-dependent. Thus, it is important for early career researchers to be actively engaged in conversations that shape team science in the field of environmental science and engineering. The environmental science and engineering community is also positioned to broaden the impact of team science in the process of resolving grand societal challenges. Our efforts will help promote best practices of team science in other disciplines.

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