Climate Change, Human Displacement, and STEM Education: Toward a More Transdisciplinary and Inclusive Culture of Science

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In this chapter I discuss opportunities for undergraduate education to support STEM scholars and students in centering social justice so that science can more meaningfully address global challenges such as the forced migration of people living in regions on the front lines of climate change. Traditional academic training structures in the STEM fields pose challenges for broadening STEM, so I suggest ideas for academic experiences that incorporate human dimensions into science education. As an example, the *Grand Challenges* program at Vassar College, which I helped found and direct, is an initiative that supports students and faculty in developing perspectives and skills that transcend traditional disciplines and in building community to meet global grand challenges, such as

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B. Murray et al. (eds.), *Migration, Displacement, and Higher Education*, Political Pedagogies,
https://doi.org/10.1007/978-3-031-12350-4_18

climate change.[1] By creating pathways for students, faculty, and staff to form communities of practice, the *Grand Challenges* program examines the culture and practice of STEM fields and seeks to cultivate an *Inclusive Excellence* framework in which science can excel only when its practitioners bring diverse perspectives, lived experiences, knowledges, and skills to solving global challenges.

A major driver of human displacement is climate change, especially the cascading impacts upon coastal cities and communities. As understood by science, these effects—rising sea level, extreme weather events, seawater intrusion, and coastal erosion, among others—threaten the continued stability of coastal cities and towns. Many residents confront the reality that the local physical environment is changing dramatically, making it impossible for them to remain in their homes. According to the Organization for Economic Cooperation and Development, rising sea level may displace as many as 40 million people in major cities alone. Human displacement along shorelines is a global emergency, and the need to protect and sustainably manage ocean resources is critical. In small-island developing states, for example, displacement threatens entire economies, communities, and cultures. Many developing nations are located in low-lying regions of the global south, disproportionately affected by tropical storms and sea-level rise.

Science and engineering are necessary for understanding and responding to the challenges of climate-induced migration, yet promising solutions and mitigations cannot arise from them alone. Feasible responses emerge only through effective international collaboration among a constellation of economic, political, scientific, sociological, and cultural stakeholders—plus the communities experiencing displacement (Hind et al. 2015). For scientists and engineers to have a maximal impact in addressing both global and community-level results of climate change, they must become skilled at building collaborations across disciplines and with frontline communities

[1] The *Grand Challenges* program (https://www.vassar.edu/grand-challenges) reflects the collective vision and work of an inspiring core leadership team: Chris Bjork, Professor of Education; Jan Cameron, Associate Professor of Mathematics and Statistics; Mary Ann Cunningham, Professor of Geography; Tom Pacio, Co-Director of *Grand Challenges* and Director of Creative Arts & Institutional Grant Innovation; and José Perillán, Co-Director of *Grand Challenges* and Associate Professor of Physics & Astronomy and Science, Technology and Society. The *Grand Challenges* program is supported through a grant from Howard Hughes Medical Institute's Inclusive Excellence program. Vassar *Student Catalysts* include: Nandeeta Bala, Leslie Lim, Clarissa Longoria, Ethan Murray, Yasmin Nijem, Gissette Noriega, Michaela Olabisi, Maya Pelletier, Sohaib Nasir, Reshan Selvavelautham, Nia Smith, and Sara Ziegler.

suffering its repercussions. Undergraduate education can play a central role in helping shape students' vision for the kind of scientist or engineer they wish to become, their skills in addressing multidimensional global challenges, and their expectations that, to do excellent science, they must engage with the social and cultural dimensions of human life.

Beyond Collaborative Science

As practiced, science and engineering are intensively collaborative. If you pick out an average science research paper from the science literature today, it likely sports dozens of authors, not one. And these co-authors may be located at a dozen different institutions on multiple continents. A study on impacts of rising sea level on migration of urban coastal populations, for example, might involve an earth science lab in Egypt working to understand the dynamics of rising sea level, an ecology lab in Germany working on establishing robust plant communities to protect coastlines, an engineering firm in Brazil developing complex physical structures to combat wave surge, and an agricultural science lab in China working to understand the threat of seawater intrusion. Each of these labs operates within different educational frameworks, different cultures and languages, and different hierarchies of science. Within each lab is another constellation of collaborations and relationships. The lab may be headed by a senior professor who oversees the work of three postdoctoral researchers, two graduate students, and two research technicians, each of whom may be involved in some aspect of this international multidisciplinary project.

To scientists, it is clear that collaborative science/engineering is key to mitigating the impacts of climate change, for example, by designing carbon drawdown systems and developing engineered protection from rising sea levels and other ocean impacts. But the scientific enterprise as a whole does not explicitly value working alongside the very communities who are experiencing the direct impacts of climate change, with the real danger that scientific and engineering solutions may never become successfully implemented in frontline communities due to misalignment between what the scientists/engineers understand and what the community needs. It is one thing to develop breeds of flood-tolerant rice in genetic research labs and another for farmers to incorporate those breeds into their fields when their fields face more severe and frequent flooding.

A major challenge in bringing scientists together with frontline communities is that traditional academic training structures in Western science

remain primarily focused on the acquisition of scientific expertise. Graduate students and postdoctoral fellows cultivate a scientific worldview in the lab and typically work in isolation from larger community systems. As a result, one's conception of what it means to be a scientist often involves deliberate disconnection from the human dimensions of the problem at hand. The "lone scientist" model rewards scientists based on their individual endeavors, even when they engage in broad collaboration with other research groups in different STEM disciplines. While there is a toolkit for intercultural training, it is small. Common practices include exchange of students between labs for reciprocal training in laboratory techniques, obtaining grants to facilitate international collaborations between labs, organization of international conferences, and co-authorship. Typically, these practices do not provide opportunities to collaborate outside the sciences, so it is important to create opportunities for training scientists and engineers to acquire background in two different aspects. First, they must gain expertise working with disciplines outside the sciences. Second, they must develop sufficient interpersonal and intercultural skills to become skilled at collaborating with political, economic, and cultural stakeholders in local communities. This is where revitalized undergraduate science education comes in. We urgently need new models to train future scientists.

New Training Models in STEM: Transdisciplinary Science and Social-Ecological Systems Frameworks

To address the first challenge—collaboration across disciplines—there is growing recognition among STEM graduate training programs that scientists need to become more adept at working within a transdisciplinary framework, in which academic disciplines such as physical sciences, social sciences, and humanities come together with policy makers to develop approaches that address the multidimensional nature of complex problems, for example the urgent global issue of climate-induced displacement (Kopp 2019). For example, the Rutgers University Coastal Climate Risk & Resilience (C2R2) Initiative has launched a new graduate training program that helps science and engineering graduate students cultivate a "whole systems" approach to addressing climate change-induced migration that includes socioeconomic, ecological, and engineering perspectives. Students work in "transdisciplinary" frameworks that transcend traditional academic disciplines by incorporating policy and other practices

that address impacts of climate change on local communities. For example, they gain experience considering how the perspectives of different stakeholders, such as policy makers, engineers, or local citizens, might shape the development and implementation of potential climate mitigation strategies within a local community at risk; they learn how to communicate science to decision-makers; they learn how to work within coastal communities and local stakeholders on issues such as coastal resilience. By developing fluency in transdisciplinary communication, and by working collaboratively with local decision-makers to address flooding, erosion, and seawater intrusion into local communities, scientists and engineers can work to mitigate the threat of displacement in a more holistic way (Major 2021).

To address the second challenge—collaborating with local communities—another emerging approach uses a Social-Ecological System (SES) framework in which scientists work collaboratively within a community setting. This approach helps center the human dimensions (cultural, historical, political, and economic) in seeking mitigation, policy, engineering, or other solutions. In addressing the forced migration of populations away from coastlines, an SES framework would lead to collaborations among scientists, community members, local policy makers, and other directly affected stakeholders. As a result, the environmental management policies or other responses that affect a community can be developed from the perspective and needs of that community (Virapongse 2016).

More deliberate incorporation of SES approaches into scientific research is slowly occurring. Opportunities such as the Social Ecological Systems Training and Education Program (SESTEP) provide formal training and case studies to help practitioners cultivate a systemic worldview, co-development of knowledge, stakeholder engagement, adaptive governance, social and ecological monitoring, and responsive education and training (Kliskey et al. 2021).

A Role for Undergraduate Science Education in Shaping the Culture and Practices of Science

Given the urgent need to train globally minded, community-oriented scientists and engineers, we must consider how to support undergraduate students in gaining transdisciplinary and social-ecological experience. After all, the training of scientists does not begin in graduate school. Students begin to shape a professional identity as a scientist in college,

where we can make a great impact by helping students understand that science must be situated within a multidimensional perspective. Our academic system still prioritizes and privileges a traditional disciplinary structure in which departments train undergraduate majors within a single discipline, such as "Biology," "Chemistry," or "Psychology." The vast majority of STEM undergraduate programs in the United States focus exclusively on helping students adapt to the existing practice and culture of Western science by focusing on acquiring laboratory, field, and computational science skills. Students internalize these expectations for the scope and culture of science from the pedagogical approaches of STEM courses, the culture of research in faculty labs, and the nature of the science community at their campus. Traditional concepts of "scientific rigor" create a competitive atmosphere in STEM courses, exacerbated by students' perceptions that introductory offerings are weed-out courses. In such a pedagogical framework, it is challenging to support training in transdisciplinary and social-ecological awareness, because these topics are often seen to detract from science content.

So, how can undergraduate institutions play a role in helping students and faculty engage in science as a global collaborative enterprise that requires diverse disciplines and centers on community needs? How can we help create multiple entry points so that students and faculty alike can develop expertise not only in science, but also in forming equitable partnerships within multinational, multicultural, and multidisciplinary contexts? One approach is to create a broader toolkit of skills and knowledge by helping faculty and students incorporate more explicitly transdisciplinary and SES approaches into their academic training.

At Vassar College, we saw an opportunity to develop an initiative that would engage the entire campus community in fostering an inclusive community of science—one that could respond to complex challenges in ways that were collaborative, transdisciplinary, and engaged with communities as well as scholars. Supported by a five-year grant from the Inclusive Excellence program at the Howard Hughes Medical Institute to foster inclusion, diversity, and equity in STEM fields, we founded the *Grand Challenges* program, in which we engage a series of global challenges that transcend disciplines and cross a multitude of lived experiences. The need for such a program arose both from a desire to develop a new generation of scientists who can operate within both global and local community collaborative structures, and to address the lack of inclusion that many

first-generation and Black, Indigenous, and People of Color (BIPOC) students experience in their studies.

At the core of the *Grand Challenges* program is the formation of a two-year learning hub around a topic of global significance. Our first learning hub (2019–2021) formed around the topic of climate change. The climate change learning hub included (1) introductory courses in STEM, Social Sciences, and Humanities organized around the theme of climate change and taught by faculty committed to fostering inclusive excellence, (2) a professional development program for faculty and staff to develop culturally responsive pedagogies, (3) opportunities for students to catalyze change, and (4) community-building initiatives to bring together students, faculty, staff, and campus in informal social gatherings.

Curriculum Development

Many students come to college not only with an interest in the sciences, but with a passion for helping solve the climate crisis. Yet they often experience introductory-level STEM courses as barriers in their journey to becoming a scientist, engineer, or medical professional. This reaction is partly because the courses' content does not seem directly connected to issues of importance to the students, but also because the perceived difficulty of course material exacerbates the imposter syndrome that many students experience, especially those who do not already feel a strong sense of belonging.

To foster more inclusive classroom cultures that address real-world issues, the *Grand Challenges* program invested in helping support a diverse set of connected courses across the sciences, social sciences, and humanities. These courses explicitly addressed climate change from their own disciplinary perspective. Faculty committed themselves to inclusive practices and participated in our faculty development program. By helping faculty shift pedagogical approaches and by helping students see the direct connection between their class and real-world problems, we aimed to help students feel more welcome in their courses where science intersected with issues of social and environmental justice.

Classes in the learning hub included standard entry-level STEM courses such as introductory Chemistry, Physics, and Calculus, as well as first-year writing seminars in Sociology (*The House is on Fire*) and History (*Climate Change and International Security*). To connect students across disciplines, courses were supplemented with out-of-class lectures and

community events organized by students and faculty, such as GreenFest, a student-organized climate change symposium, and a Coral Reef Expo featuring evocative creatures crocheted during a student winter creative project. By supporting climate action both inside and outside the classroom, and by creating events that brought the humanities together with social science, one outcome has been that students feel more strongly that STEM is a multifaceted endeavor in which inclusivity and justice are foundational components.

Students emerging from these introductory-level courses had access to pathways for continuing their exploration of the intersection of science and social/environmental justice. For example, our campus adopted a new curricular offering called the Intensive, in which a faculty member and a small group of students focus on a topic of mutual interest. The *Grand Challenges* program supported development of the *Creating Communities That Care* Intensive, in which faculty and students explored different dimensions of inclusion. In one iteration, *Creating Community in the Climate Change Movement*, students focused on approaches to building diverse and equitable communities committed to finding solutions for global climate change, and they explored how to apply one's expertise and amplify others' work to build collaborative communities to create change. Students co-created the syllabus for the course, focusing on three areas: Becoming a Transdisciplinary Translator, Finding Your Voice, and Building Community. Students read the work of two scientists who have successfully navigated a transdisciplinary and SES career in climate issues: Ayana Johnson and Bob Kopp. They are PhD scientists who focus their work on the human impacts of climate change, and who have taken different paths that intersect across science and policy. Dr. Johnson leads the Urban Lab, a think tank for developing solutions for climate change, and Ocean Collectiv which seeks solutions to climate change that are founded in social justice. Dr. Kopp is an academic scientist who publishes broadly on the need for scientists to become transdisciplinary translators of climate change action. Both were invited to campus to give a talk and engage in a student-moderated conversation about how to become justice-minded scientists who can collaborate on climate solutions embedded in the needs of affected communities.

Vassar's new transdisciplinary curriculum on *Migration and Displacement Studies* offers our STEM students a new opportunity to directly study how their fields might be involved in addressing the global challenge of forced migration. The new curriculum opens a pathway for

students majoring in traditional disciplines to immerse themselves in courses, experiential work, and capstone projects aimed at understanding and addressing this global challenge. The curriculum integrates theory with practice to enhance classroom learning, translate inert knowledge into action, and promote community partnerships (locally, regionally, and globally). Science majors emerging from introductory courses might take the *Lexicon of Forced Migration* course in the Fall semester of their sophomore year, work with newly settled refugees in the Hudson Valley in the Spring semester, then engage in summer research with science faculty that might then develop into capstone projects. In the summers of 2020 and 2021, for example, students majoring in Psychological Sciences and in Science, Technology, and Society worked as research fellows studying the psychology of trauma in displaced individuals, as part of Vassar's summer Undergraduate Science Research Institute (URSI) and in close collaboration with our consortium partners at the New School (see Adam Brown and Alexa Elias's essay in this collection).

Professional Development for Faculty and Staff

As educators, academic advisors, and research mentors, STEM faculty profoundly shape students' conception of the scope and culture of science. Helping faculty become more culturally responsive educators who can make social justice an explicit goal of science is a primary objective of the *Grand Challenges* program. This begins with helping faculty reflect on ways to promote a more inclusive and equitable academic environment. For example, in summer 2021, we worked with the Inclusion Diversity Equity Access Leadership Center (IDEAL—https://www.smm.org/ideal-center), directed by Liesl Chatman and their team at the Science Museum of Minnesota, to offer faculty and staff the opportunity to develop a cohort of "change agents." In a weeklong workshop, participants engaged critical concepts in systems thinking, systems of oppression, and growth/fixed mindsets, while interrogating their own perceptions of academic culture. Participants also learned to engage in new practices of communication designed to ensure that diverse viewpoints are heard and valued. Through the week, the sense of individual and collective responsibility to challenge inequitable practices within classrooms, departments, and across administrative offices prompted participants to develop actionable plans that included new pedagogical approaches for fostering equity in their teaching, advising, and mentorship. As a result, faculty are testing

ways to engage students in more culturally responsive and equitable pedagogies. For example, faculty are designing small-group work assignments in which the sharing of knowledge and experiences among students is critical. In so doing, faculty help students create a vision of science in which diverse perspectives are necessary for designing robust solutions.

Opportunities for Students to Catalyze Change

A major focus of the *Grand Challenges* program has been to support students in broadening the traditional conception of what it means to do science, by creating opportunities for them to become agents of change in the STEM community. We initiated a new *Student Catalyst* summer research program that was run alongside the laboratory summer science program. In the *Catalyst* program, students worked collaboratively with faculty and staff to design research and action projects aimed at identifying barriers to inclusion in STEM, and then develop approaches to remove those barriers. In their work, students learn to engage both the published literature and the impacted community in developing an understanding of the problem at hand and possible solutions. Students' ideas are then developed into pilot programs tested the following academic year. In Summer 2021, student catalysts focused their project ideas on improving the first-year experience, especially for students who are the first in their families to attend college. Using surveys that identified the ways in which students felt a lack of cultural, economic, or academic support, the *Catalysts* devised program ideas to respond. Their projects are now in the process of being implemented through collaborations with departments and other student-facing offices. For example, the Building STEM Community Among BIPOC Students addresses the need to foster a sense of belonging and mattering among students; the First-Year Laboratory Intensive aims to connect students with faculty from diverse STEM fields so that students can experience science labs before they take their first science course; and Textbook Affordability and Accessibility aims to remove the barrier of cost from access to course materials. The skill and creativity of these students—in bridging science and social justice, in bringing together published literature on inclusive education with demonstrated needs of Vassar students, and in navigating the infrastructure and practices of the academic environment—are needed to navigate issues that span science and human dimensions.

Community Building

Embedded throughout the *Grand Challenges* program is an awareness of building community at all levels: among students, staff, and faculty; across disciplines; between the academic community and the broader world. To foster our capacity to build community, we have supported students in creating their own communities (BIPOC in STEM and GreenFest were mentioned earlier); in creating community with their professors through "Catalytic Cafes" in which faculty and students explore what it means to bring one's whole self to a life in science; in creating community across campus through workshops such as a storytelling workshop in which students, faculty, and staff developed stories about our experiences in science; and in organizing large community events, such as the Coral Reef Expo with over 100 participants crocheting corals for a giant exhibit.

Faculty and students in many Vassar courses and Community Engaged Learning projects work in partnership with local and regional organizations that are beginning to consider how climate change will affect their missions and programs. These partnerships not only build community but also provide opportunities for students to engage in transdisciplinary collaboration and social-ecological systems research.

Vassar students taking a Conservation Biology course or working in collaboration with the Environmental Cooperative at Vassar Farms, for example, work on climate reforestation plans using plant species capable of thriving in local conditions predicted in local climate projections. Students in the Geographic Information System (GIS) mapping courses and entry-level Environmental Studies courses carry out community GIS mapping projects with local organizations, such as in the City of Poughkeepsie. The students' skills in GIS mapping assist the local community in planning for climate issues, generating greenhouse gas assessments, working toward Climate Smart Community certification, creating natural resource inventories, and addressing Community Preservation needs. In the future, regional projects can be developed to evaluate the likelihood of climate displacement in the Hudson Valley region, and to examine the potential for local areas to serve climate refugees by providing resettlement locations.

The GIS mapping work has been so motivating that Vassar students created the *Hudson Valley Mappers* to engage the local community in

humanitarian mapping projects. This student organization is registered as a campus chapter of Youth Mappers, an organization created in 2015 by the U.S. Agency for International Development GeoCenter to address humanitarian issues. Youth Mappers has become a global network of over 300 chapters in 65 countries (https://www.youthmappers.org/). Some Youth Mapper projects address climate-induced displacement, for example, humanitarian aid in response to flooding in India, Sri Lanka, and Japan. Mappers use satellite images of local areas to digitize local infrastructure such as roads and buildings, enabling humanitarian relief teams to accurately estimate the size of affected populations and to determine where households are located and how to reach them.

Conclusion

The displacement of communities due to climate change is a global grand challenge, and science is at the heart of many of the possible solutions—minimizing climate warming, engineering coastal protection, creating resilient economies, and minimizing effects on individuals. But because traditional scientific training offers students few opportunities to engage the cultural and human dimensions of their work, scientists can be ill-equipped to engage in the kind of intercultural, interdisciplinary, and community-based collaborations necessary for tackling climate-induced displacement. At Vassar, through professional development, curricular development, empowerment of student voices, and explicit community building, the *Grand Challenges* program offers one approach to incorporating social and environmental justice into the core of undergraduate scientific training. The scientists who emerge are able to navigate both the scientific and cultural elements of addressing complex challenges. Although founded with the goal of making science a more welcoming and responsive community at Vassar, it has become clear that the *Grand Challenges* program helps faculty and students build community to address climate change across disciplines. By supporting intercultural awareness in STEM fields, we are preparing science majors with experiences, perspectives, and skills to help them become the transdisciplinary and social-ecological scientists and engineers that our world needs.

Further Reading

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