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Equitable Exchange: A framework for diversity and inclusion in the geosciences

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Key Points:

- We need new mechanisms to broaden participation in the geosciences
- Co-production of science with local underrepresented communities may improve societal relevance and diversify geosciences
- The Equitable Exchange creates an ethical framework for co-production and inculcates skills related to cultural competency and attention to inclusive practices into the geosciences

Abstract

We highlight a mechanism for the co-production of research with local communities as a means of elevating the social relevance of the geosciences, increasing the potential for broader and more diverse participation. We outline the concept of an "equitable exchange" as an ethical framework guiding these interactions. This principled research model emphasizes that "currencies"- the rewards and value from participating in research - may differ between local communities and geoscientists. For those engaged in this work, an equitable exchange emboldens boundary spanning geoscientists to bring their whole selves to the work, providing a means for inclusive climates and rewarding cultural competency.

Plain Language Summary

This paper expands on prior work to outline an ethical framework to guide research co-created with local communities. We propose appreciation for the differing perspectives geoscientists and local community members bring to problem-solving and to creating knowledge around questions and issues pertinent to geoscience. A respectful and "Equitable Exchange" between individuals working together in these contexts can foster greater scientific creativity and societal relevance, and may ultimately broaden and diversify participation in the geosciences.

1 Introduction

In the 50 years that the National Science Foundation has been keeping demographic statistics, there is growing frustration about the continuing lack of diversity, and a compelling need for both equity and inclusion in, Science, Technology, Engineering and Mathematics (STEM) in the United States' workforce (Bernard & Cooperdock, 2018), despite growing demographic diversity in the population at large. Within the geosciences (Earth, Atmosphere, Ocean and Polar Sciences), there is a current wave of energy and attention to issues of equity and social justice in geoscience spaces that is long overdue. Calls to action (Morris et al., 2020; Ali et al., 2020), publications (e.g. Marín-Spiotta et al., 2020; Chen et al., 2020), personal stories (#BlackAndStem twitter feed), and even entire new centers (e.g. AGU Ethics and Equity Center) are pushing the edges and reforming the way we approach broadening participation. Proposed strategies to accelerate demographic and ethno-cultural representation have largely failed. These strategies frequently portray the lack of diversity as a problem of unequal access (e.g., via affordability or as a consequence of structural racism), or also one of unequal interest. With evidence existing for both perspectives (Dutt, 2020; Posselt, 2020), one mechanism to broaden participation in the geosciences is to actively engage individuals who are outside of the scientific mainstream to integrate inclusion into the definition of geoscience research.

Here, we hope to contribute to this conversation by illuminating a mechanism for change focused on expanding the geoscience discovery space that necessarily requires a coincident focus on inclusion. In particular, we describe the value in identifying how gains may be made around justice, equity, diversity, and inclusion via work in the realms of citizen science, community-based research, participatory research, and place-based research. By definition, these research approaches invite a broader membership in the geoscience endeavor, and require an attention to engagement and cultural competency. Because there is a deep history of doing this work across the whole of science, we argue that there is great potential for rapid transformation by elevating, championing, rewarding and expanding existing efforts rather than building from the ground-up.

Approaches that engage a wider range of the public will require a broadening of the definition and pursuit of the geosciences. Knowledge co-production[1] offers one framework that shifts knowledge creation away from a uni-directional transfer of information developed by scientific experts to end users in society towards a broader exchange of knowledge, skills and interpretation between mainstream researchers and a wide range of invested publics. Place-based research that is authentically inclusive of local communities, and especially sensitive to elevating local and traditional knowledge, and knowledge-holders, is one form of co-production. We argue here that emboldening this kind of contextualized research that is place-based, tied to community, and addresses societal issues expressed locally, can increase the sense of belonging for underrepresented groups in the geosciences in terms of interest, self-efficacy, and identity (see also Callahan et al., 2018; Figure 1).

In fact, the nature of current research challenges facing geosciences can enable this expansion. Global biophysical change now rapidly occurring within the Earth system affects billions of people and cannot be separated from human behavior, economics and equity (Leach et al., 2018; Steffen et al., 2015). The resulting research challenges are transdisciplinary, even convergent, and require innovation beyond the sole perspective of mainstream science. Thus, the geosciences could expand through consideration of social and societal relevance when gauging the importance and urgency of questions, incorporation of citizen science and other forms of public inclusion, and a robust ethical framework for engaging with geographic, ethnographic and "of practice" communities.

Here we propose ***Equitable Exchange*** (EE) as a process of co-production that is grounded in ethical considerations about power, that incorporates voices and approaches beyond mainstream science, and that expects cross-cultural competency of its adherents. A basic tenet of EE is that a variety of currencies, or the information and accolades of value to participants, will be exchanged in the course of science. Some will be knowledge-based, others will include financial and/or resource-based exchange, and yet others will support research-informed decision-making and the human dimensions of risk management. Centering co-production in equity[2] requires participants to ask who will benefit from a given interaction, to move beyond the transactional to focus on relationships and trust, and to consider the collective good to balance disparities.

We posit that the practice of EE fosters greater diversity and inclusion in the geosciences by enabling a wider range of publics to be valued as co-creators, empowering individuals to step into science while maintaining strong, central membership in their community.

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[1] A number of terms have been used to describe community-engaged science, including co-production or co-creation of knowledge, as well as community-based, place-based, and participatory action research. There is an extensive literature in these approaches (e.g. Haraway, 1988; Lazarus et al., 2016; Strasser et al., 2019). Brunson & Baker (2015) also expand a definition of "translational ecology," emphasizing new training platforms for competencies needed by scientists to engage in boundary spanning research in the environmental sciences.

[2] How equity is understood has significant consequences for what actions and changes may be deemed necessary. We define equity as "reconfiguring structures, cultures, and systems to close disparities and empower marginalized groups" (Posselt, 2020, p. 3).

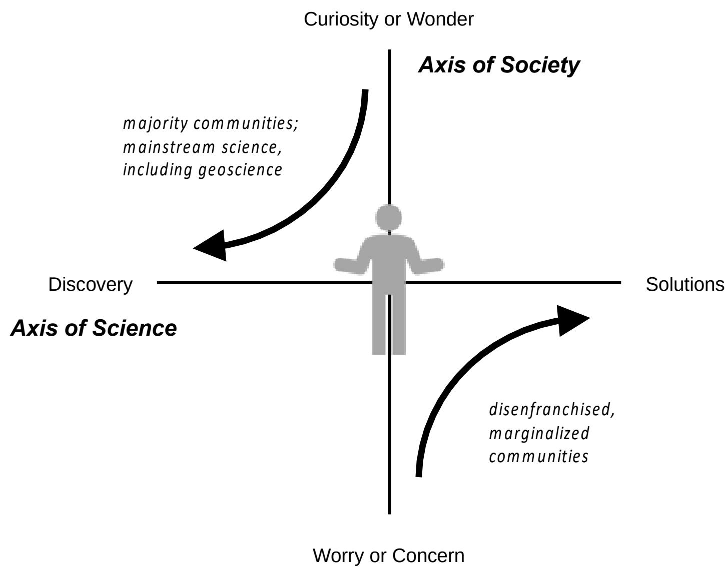

Figure 1. How individuals relate to science. The Axis of Science describes a range of disciplines arrayed according to the classic basic-applied continuum. The Axis of Society describes the range of affect any individual, group or community might display with respect to their interactions with, regard for, and feelings about science. Academic science often prioritizes discovery of the natural world to satisfy curiosity and add to human knowledge. Individuals from disenfranchised or marginalized communities, often synonymous with populations underrepresented in STEM, may gravitate more towards science as a practical tool for problem-solving, or actionable science. Boundary spanners (gray) are individuals able to maintain membership in both worldviews.

2 Geoscience Research at the Intersection of Place and Community

A common paradigm for geoscience research is discovery emanating from wonder: curiosity-driven data collection and analysis centered on discovering how the natural world works (Berling et al., 2019; Figure 1). Historically, discovery science has largely been implemented by testing and advancing discipline-specific theory, which has made and will continue to make important contributions to human knowledge.

However, discovery science and the institutional structures that have sustained and celebrated this approach have a poor record of inclusivity. Too often, people who seek to incorporate different approaches and ideas, including those who look and act different, espouse different traditions of knowledge-gathering, and/or elevate non-degree holders as experts are eschewed relative to those who conform to mainstream scientific norms. For example, Weissmann et al. (2019) highlight the prevalence of "low-context" learning in U.S. university science culture, which focuses on individual work and linear learning not situated in place, issue or problem - even as many underrepresented students are motivated by high-context work associated with localized problem-solving.

Solutions science, also known as actionable science (Theobald et al., 2015; Palmer, 2012) is another paradigm in geosciences, emerging not as a replacement, but as a complement to the discovery approach. While not devoid of theory, solutions science emanates from the very real and often short-term need to address particular problems and/or tackle issues resulting from inequities, including but not limited to those defining environmental justice (e.g. Ramirez-

Andreotta et al., 2016). Because these issues are by definition place-based, and often affect marginalized or disenfranchised communities, embracing solutions science may provide a framework for increasing the societal relevance of geoscience. Indeed, this shift is already occurring as many geoscientists, from across a range of identities, seek to use their research to solve problems broadly associated with societal need (Gosselin et al., 2016; Stewart, 2016).

However, we note that historically marginalized groups may view even solutions-based research with suspicion and distrust when it is led by scientists and managers from institutions external to the community and/or from majority demographics (Pandya, 2012). Histories of exploitation and colonialism have legacies in many mainstream geoscientists' work: some fail to consider local values, cultures and knowledge; others fail to involve community members directly in the research process (Cuker, 2001; David-Chavez & Gavin, 2019), even when engaging in place-based work. Similarly, within communities that continue to experience loss of land, rights, jobs, culture or traditions, problem-based approaches to science learning are likely to fall short of inclusion because they are rooted in the assimilation of indigenous uniqueness into a larger (i.e. mainstream science) whole (Deloria & Wildcat, 2001). More authentic forms of co-creating knowledge could help bridge social and symbolic boundaries between marginalized communities and geoscience professionals and educators, and expand both discovery and solutions science.

Place-based research focused on a compelling location based on its environmental conditions is not new to the geosciences (Semken, 2005; Londono et al., 2016). The iconic direct record of rising atmospheric CO_2 concentrations used worldwide comes from the Mauna Loa Observatory, a facility intentionally situated high on an island volcano in the middle of the Pacific Ocean to maximize distance from continental land masses (Keeling & Whorf, 2005), albeit without attention to the socio-cultural values of the site, or incorporation of the indigenous community into the science (see no mention in Keeling, 1998). Site selection for these measurements is comparable (in geoscience) to the location of a suite of telescopes on top of neighboring Mauna Kea because of the quality of observations possible there. Both of these examples underscore the problems with place-based research driven only by scientific goals and constraints, without consideration of community values and goals (Alegado, 2019). The summit of Mauna Kea is sacred to Indigenous Hawaiians, and astronomers' insistence on continuing to build telescopes there has led to increasing conflict that further marginalizes the Indigenous community and also threatens the continuity of astronomical observations (Kahanamoku et al., 2020; Borrelle et al., 2020; Spencer et al., 2020). This conflict contrasts with place-based science that is rooted in local communities. For example, recent research on the flanks of Mauna Kea (among other places in Hawai‘i) makes use of both the special features of the island and Indigenous knowledge of traditional agriculture to evaluate landscape-ecosystem interactions based on community needs (Lincoln et al., 2018). Likewise, the He‘eia National Estuary Research Reserve exemplifies a contemporary Indigenous Community and Conserved Area of reciprocal research and management collaboration with the Indigenous people and local community (Winter et al., 2020). David-Chavez & Gavin (2019) frame this in Indigenous communities as a "collegial" approach, where co-creation grants community members the authority to lead, thereby disrupting colonial legacies of power within the academy.

3 Research as an Equitable Exchange

To advance and link the scholarship and impact of discovery and of application (Boyer, 1990), we propose a vision for geoscience research distinguished by scientists and local community members co-constructing an “Equitable Exchange” (EE) of knowledge, values, and cultural reciprocity.

What is exchanged? For engagement with communities who have historically lacked access to power, self-determination and/or decision-making regarding land and resources the exchange requires conscious consideration of equity and even reparation. If one goal in community-based research is to create, at a minimum, a collaborative or collegial approach, rather than one that is extractive we propose starting with an understanding of what currencies could be exchanged as a way to foster equity and agency while maintaining individuality and tradition. Within the sciences, currencies include published manuscripts, grant awards, peer recognition and awards, and promotion and tenure. From the perspective of a place-based and/or ethnographic community member, currencies may include resources to address local human health and/or environmental management issues; recognition of knowledge, knowledge-holders and knowledge systems; data sovereignty; funding; and linkage to and advancement of K-16 educational opportunities. A failure to recognize and/or translate across currency systems can limit or even derail collaboration. Thus a successful EE must include efforts to ensure that all parties are rewarded in culturally-relevant currencies - ones discovered through dialogue and transparent processes aimed at developing mutual understanding and, more fundamentally, trust. For work with underrepresented communities to facilitate their empowerment also necessitates that community members experience greater benefit and authority in collaborations than has historically been the case. This underscores our emphasis on equity, which involves recalibrating scales of power and privilege. Implementing this approach within geoscience will require careful attention to project design, project teams, funding amounts and allocations, expectations for project deliverables, recognition of a diversity of knowledge, and training for all team members in cultural competencies. We note that these issues are not easy, and will require tenacity, courage and time.

Knowledge co-constructions within an EE can be abstract, in the form of collaborative brainstorming or development of conceptual models. However, it is also likely that the exchange will be explicit, for instance: local community members contributing knowledge that informs research site selection; mainstream geoscientists contributing expertise in data collection and/or analysis to address a particular environmental issue; or the realization of multiple information collection schemes flowing from traditional knowledge and environmental science. In each of these cases, it becomes critical to consider what distinguishes an exchange as equitable. An honestly and transparently realized understanding of who owns, controls, analyzes, interprets and communicates the data and the science, and to what ends, is essential; as is who is paid, who learns, and who gets credit. Scientists entering or involved in an EE thus accept the need for several specific activities of co-construction: cultural translation across the languages of science and place-based, ethnographic communities; incorporating traditional and local knowledge into the development, process and interpretation of research; and creating and reinforcing mechanisms that allow all participants to be heard and respected, in addition to explicit compensation.

The EE embraces the fact that the scientific process and its outcomes are mutually “owned,” and with this plurality comes moral and ethical responsibilities that all parties must co-create, acknowledge and navigate. Envisioned as a long-term commitment, an EE should, over time, build trust between parties who wish to span discovery-and-solutions spaces (Quigley et al., 2000). This trust is generative, such that future scientific work is enabled, as is the creation of a more positive image of mainstream science for younger generations within the community; those who may participate as boundary spanners in the future.

Who is involved? Developing a geoscience-focused EE begins with people coming together to articulate and work on a challenge or question that is of mutual interest, which may stem from curiosity and/or concern. From the outset, the project team must include both mainstream geoscientists and key community members. As a consequence, the process holds space for multiple ways of knowing, including traditional cultural wisdom, traditional disciplinary knowledge, and practical experience (Basso, 1996). We emphasize that this work requires the support and cultivation of “boundary spanners” - individuals with the unique leadership skills and interests to traverse cultures and guard against extractive practices (e.g. Safford et al., 2017). Ideally, boundary spanners possess dual membership in and/or permission to act within both geoscience and the local community, and are therefore able to understand the rules defining each institutional structure, and facilitate cultural translation between them (Meyer et al., 2016). An EE may also include: community leaders (who may be boundary spanners themselves) who facilitate access to communities; content experts who possess relevant local, cultural, and/or traditional knowledge; researchers with project-relevant expertise; and students and other learners who are entrained as part of the social contract inherent both in the academy and the community to empower future generations.

Although boundary spanners are often the fulcrum of exchanges between underrepresented communities and mainstream science, in the geosciences they are currently rare. One reason may be that working in-community, on local, place-based issues that may be actionable science but do not count as discovery in the senses of either theory construction or knowledge acquisition, simply does not pay the currencies that academia requires of scientists to be successful. A second reason is that underrepresented scientists are continually asked to code-switch, a mentally and socially exhausting exercise that may result in success in both worlds, or potentially rejection by both as not authentic. These reasons point to fundamental challenges for boundary spanners who experience implicit and explicit messages that erode a sense of belonging in the geosciences (e.g. Pickrell, 2020). In our vision, exercising the EE broadly will elevate new currencies and rewards for co-produced research across the geosciences, elevating the status of boundary spanners and their skillsets while providing a ground-up mechanism for raising expectations for cultural competencies and the creation of an inclusive research climate for everyone.

Without downplaying other functions and partners in an EE, we propose that supporting the development of mainstream|community boundary spanners will increase the success of community-based research, and enhance the relevance of geoscience to underrepresented populations. This is central to the proposal of Brunson and Baker (2015) to transform graduate education to foster boundary spanner characteristics in service of a “translational ecology.” Because geoscience boundary spanners are, by definition, geoscientists, their leadership can also increase the visibility of geoscience career paths. As such, elevating the opportunities and status of boundary spanners may provide a mechanism for more diverse representation in geoscience fields.

The challenge of boundary-spanning inherent in EE is one of collaboration across difference. By encouraging boundary spanners as skilled and knowledgeable agents to implement an EE, a supportive framework for inclusive research in the geosciences can be designed and refined, effectively extending the science of geoscience. In transforming the rules about who has influence on science and on what basis, as well as whose interests' scientific activity ultimately serves, the EE could advance structural change in geoscience disciplines to confront issues of power and systemic racism, and inform other fields where place-based and/or community-based research can occur.

4 A Way Forward

We acknowledge that this framework will require new focus on compensating and investing in communities alongside training of geoscientists, collaboration with social scientists, and elevation of those who are already engaged in this work to higher status positions. It will require grappling with social dynamics of research that are often taken for granted, and negotiating incentive structures that do not always support research with long timelines and unconventional products. The contribution of different ways of knowing – local and indigenous knowledge - will similarly warrant recognition, compensation, and the capacity of the research endeavor to incorporate these needs. Already, however, community- and place-based work is gaining credence within the geosciences. In-practice professorships in environmental science (e.g., Professors-of-Practice within the Julie Ann Wrigley Global Institute for Sustainability at Arizona State University) have elevated community-based work as a position requirement. Scientific societies have created clearinghouses that connect communities and geoscientists (e.g., Thriving Earth Exchange), and recognize exemplary in-community work (e.g., American Society of Limnology & Oceanography's Ruth Patrick award). An emphasis on convergence research and diversity at the National Science Foundation has resulted in initiatives such as Coastlines and People. We feel hopeful that there is much potential to encourage, support, and expand these efforts to an emphasis on broadening participation and spaces that can support the tenets of an EE.

5 Conclusions

Understanding the ongoing changes, emerging risks, and local-to-global hazards associated with the Anthropocene (Steffen et al., 2007) is clearly within the purview of the geosciences. These issues have community implications and require community wisdom. A demographically homogenous population of geoscientists limits the likelihood that these challenges will be met and decreases the likelihood that findings will be accepted by the full diversity of humanity at a time when the public trust in science is in crisis (Oreskes, 2019) Given the rapid shift in the demographics of the United States (Garza, 2015), it is imperative that the geosciences explore strategies for engaging historically underrepresented groups--strategies that resonate both with the sensibilities of scientists, and with those of the communities who have traditionally been excluded or have elected not to join. In advancing ethical and inclusive approaches to geoscience research that celebrate its societal relevance, we can broaden participation, raise the public profile of the geosciences, and increase the creativity and innovation needed to navigate modern environmental challenges.

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References

Alegado R.A**.** (2019). Opponents of the Thirty Meter Telescope fight the process, not science. *Nature*, **572**(7767), 7. doi: 10.1038/d41586-019-02304-1

Ali, H. (2020). "Call for a Robust Anti-Racism Plan for The Geosciences" https://www.change.org/p/geoscientists-call-for-a-robust-anti-racism-plan-for-the-geosciences

Basso, K. H. (1996). Wisdom sits in places: Landscape and language among the Western Apache. UNM Press.

Berling, E., McLeskey, C., O'Rourke, M., & Pennock, R. T. (2019). A new method for a virtue-based responsible conduct of research curriculum: pilot test results. *Science and engineering ethics*, **25**(3), 899-910. https://doi.org/10.1007/s11948-017-9991-2

Bernard, R. E. & Cooperdock, E. H. (2018). No progress on diversity in 40 years. *Nature Geoscience*, **11**(5), 292. https://doi.org/10.1038/s41561-018-0116-6

Boyer, E. L. (1990). *Scholarship reconsidered: priorities of the professoriate*. Princeton, NJ: Princeton University Press.

Brunson, M.W., Baker, M.A. (2015). Translational training for tomorrow's environmental scientists. *J Environ Stud Sci* **6,** 295–299 https://doi.org/10.1007/s13412-015-0333-x

Callahan, C.N., LaDue, N.D., Baber, L.D., Sexton, J., van der Hoeven Kraft, K.J., & Zamani-Gallaher, E.M. (2018). Theoretical perspectives in increasing recruitment and retention of underrepresented students in the geosciences. *Journal of Geoscience Education*, ***65***(4), 563-576. https://doi.org/10.5408/16-238.1

Chen, J. A., Tutwiler, M. S., & Jackson, J. F. L. (2020). Mixed-reality simulations to build capacity for advocating for diversity, equity, and inclusion in the geosciences. *Journal of Diversity in Higher Education.* Advance online publication. https://doi.org/10.1037/dhe0000190

Cuker, B. (2001). Steps to increasing minority participation in the aquatic sciences: Catching up with shifting demographics. *ASLO Bulletin*, **10**(2), 17-21.

David-Chavez, D. M., & Gavin, M. C. (2018). A global assessment of Indigenous community engagement in climate research. *Environmental Research Letters*, **13**(12), 123005.

Deloria Jr., V. & Wildcat, D. R. (2001). *Power and place: Indian education in America*. Golden, CO: Fulcrum Pub.

Dutt, K. (2020). Race and racisms in the geosciences. *Nature*, **13**, 2-3.

Garza, C. (2015). Reaching out to underserved communities. *Marine Technology Society Journal*, **49**, 8-12.

Gosselin, D., Burian, S., Lutz, T., & Maxson, J. (2016). Integrating geoscience into undergraduate education about environment, society, and sustainability using place-based learning: three examples. *Journal of Environmental Studies and Sciences*, **6**(3), 531-540. https://doi.org/10.1007/s13412-015-0238-8

Haraway, D. (1988). Situated Knowledges: The Science Question in Feminism and the Privilege of Partial Perspective. *Feminist Studies* **14**(3): 575-599.

Keeling, C.D. (1998). Rewards and penalties of monitoring the earth. *Annu. Rev. Energy Environ.*, **23**: 25-82.

Keeling, C. D. & Whorf, T. P. (2005). *Atmospheric carbon dioxide record from Mauna Loa.* Carbon Dioxide Research Group, Scripps Institution of Oceanography, University of California La Jolla, California.

Lamont, M. & Molnár, V. (2002). The study of boundaries in the social sciences. *Annual Review of Sociology*, **28**, 167-95. https://doi.org/10.1146/annurev.soc.28.110601.141107

Lazarus, H., J.K. Maldonado, B. Gough. "The Rising Voices: Building bridges between scientific and indigenous communities." *Natural Hazards Observer*, Vol XL(4), April 26, 2016. https://hazards.colorado.edu/article/the-rising-voices-building-bridges-between-scientific-and-indigenous-communities

Leach, M., Reyers, B., Bai, X., Brondizio, E. S., Cook, C., Díaz, S., Espindola, G., Scobie, M., Stafford-Smith, M.,& Subramanian, S. M. (2018). Equity and sustainability in the Anthropocene: a social–ecological systems perspective on their intertwined futures. *Global Sustainability*, *1*.

Lincoln, N.K., J. Rossen, P. Vitousek, J. Kahoonei, D. Shapiro, K. Kalawe, M. Pai, K. Marshall, K. Meheula. 2018. Restoration of ʻĀina Maloʻo on Hawaiʻi Island: Expanding Biocultural Relationships. *Sustainability*, **10**, 3985; doi:10.3390/su10113985

Londono, S. C., Garzon, C., Brandt, E., Semken, S., & Makuritofe, V. (2016). Ethnogeology in Amazonia: Surface-water systems in the Colombian Amazon, from perspectives of Uitoto traditional knowledge and mainstream hydrology. Geological Society of America Special Papers, 520, SPE520-20. https://doi.org/10.1130/2016.2520(20)

Marín-Spiotta, E., Barnes, R. T., Berhe, A. A., Hastings, M. G., Mattheis, A., Schneider, B., & Williams, B. M. (2020). Hostile climates are barriers to diversifying the geosciences. *Advances in Geosciences*, ***53***, 117-127.

Meyer, S. R., Levesque, V. R., Hutchins-Bieluch, K., Johnson, M. L., McGreavy, B., Dreyer, S., & Smith, H. (2016). Sustainability science graduate students as boundary spanners. *Journal of Environmental Studies and Sciences*, **6**(2), 344-353. https://doi.org/10.1007/s13412-015-0313-1

Morris, V., White, L., Fuentes, J.D., Atchinson, C.L., Smythe, W.F., Burt, M., Williams, L., Tripati, A., Demoz, B.B., Armstrong, R.A. (2020). "A Call to Action for an Anti-Racist Science Community from Geoscientists of Color: Listen, Act, Lead" https://notimeforsilence.org/.

Oreskes, N. (2019). *Why trust science?*. Princeton University Press.

Pickrell, J. "Scientists push against barriers to diversity in the field sciences" (2020). https://www.sciencemag.org/careers/2020/03/scientists-push-against-barriers-diversity-field-sciences

Posselt, J. R. (2020). Equity in science: Representation, Culture, and the Dynamics of Change in Graduate Education. Stanford University Press.

Quigley, D., Sanchez, V., Goble, R., Handy, D., & George, P. (2000). Participatory research strategies for nuclear risk management for native communities. *Journal of Health Communications*, **5**(4), 305-333. https://doi.org/10.1080/10810730050199123

Rao, H., Monin, P., & Durand, R. (2003). Institutional change in Toque Ville: Nouvelle cuisine asan identity movement in French gastronomy. *American Journal of Sociology*, **108**(4), 795-843. https://doi.org/10.1086/367917

Safford, H. D., Sawyer, S. C., Kocher, S. D., Hiers, J. K., & Cross, M. (2017). Linking knowledge to action: the role of boundary spanners in translating ecology. *Frontiers in Ecology and the Environment*, **15**(10), 560-568.

Semken, S. (2005). Sense of place and place-based introductory geoscience teaching for American Indian and Alaska Native undergraduates. Journal of Geoscience Education, 53(2), 149-157.

Steffen, W., Crutzen, P. J., & McNeill, J. R. (2007). The Anthropocene: are humans now overwhelming the great forces of nature. *AMBIO: A Journal of the Human Environment*, **36**(8), 614-622. https://doi.org/10.1579/0044-7447(2007)36[614:TAAHNO]2.0.CO;2

Steffen, W., Broadgate, W., Deutsch, L., Gaffney, O., & Ludwig, C. (2015). The trajectory of the Anthropocene: the great acceleration. *The Anthropocene Review*, **2**(1), 81-98.

Stewart, I. (2016). Sustainable geoscience. *Nature Geoscience*, **9**(4), .262. https://doi.org/10.1038/ngeo2678

Strasser, B., Baudry, J., Mahr, D., Sanchez, G., & Tancoigne, E. (2019). " Citizen Science"? Rethinking Science and Public Participation. *Science & Technology Studies*, **32**, 52-76.

Weissmann, G.S., Ibarra, R.A., Howland-Davis, M., & Lammey, M.V. (2019). The multicontext path to redefining how we access and think about diversity, equity, and inclusion in STEM. *Journal of Geoscience Education*, **67***(4), 320-329. https://doi.org/10.1080/10899995.2019.1620527*.

Winter, K. B., Y. M. Rii, F. A. W. L. Reppun, K. DeLaforgue Hintzen, R. A. Alegado, B. W. Bowen, L. L. Bremer, M. Coffman, J. L. Deenik, M. J. Donahue, K. A. Falinski, K. Frank, E. C. Franklin, N. Kurashima, N. Kekuewa Lincoln, E. M. P. Madin, M. A. McManus, C. E. Nelson, R. Okano, A. Olegario, P. Pascua, K. L. L. Oleson, M. R. Price, M. J. Rivera, K. S. Rodgers, T. Ticktin, C. L. Sabine, C. M. Smith, A. Hewett, R. Kaluhiwa, M. Cypher, B. Thomas, J.-A. Leong, K. Kekuewa, J. Tanimoto, K. Kukea-Shultz, A. Kawelo, K. Kotubetey, B. J. Neilson, T. S. Lee, and R. J. Toonen. 2020. Collaborative research to inform adaptive comanagement: a framework for the He‘eia National Estuarine Research Reserve. *Ecology and Society* 25(4):15. https://doi.org/10.5751/ES-11895-250415