https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

# GC Insights: Diversifying the Geosciences in Higher Education: a Manifesto for Change

Caitlyn A. Hall[1], Sam Illingworth[2], Solmaz Mohadjer[3], Mathew Koll Roxy[4], Craig Poku[5], Frederick Otu-Larbi[6], Darryl Reano[7], Mara Freilich[8], Maria-Luisa Veisaga[9], Miguel Valencia[10], and Joey Morales[11]

[1]The Honors College and Biosystems Engineering Department, University of Arizona, Tucson, Arizona, United States
[2]Department of Learning and Teaching Enhancement, Edinburgh Napier University, Edinburgh, Scotland
[3]Department of Earth and Environmental Sciences, University of Central Asia, Khorugh, Tajikistan
[4]Climate Research Lab, Indian Institute of Tropical Meteorology, Pune, India
[5]Department of Chemistry, University of York, York, United Kingdom
[6]Lancaster Environment Centre, Lancaster University, United Kingdom
[7]School of Earth and Space Exploration, Arizona State University, Tempe, Arizona, United States
[8]Scripps Institution of Oceanography, University of California San Diego, San Diego, California, United States
[9]Kimberly Green Latin American and Caribbean Center, Florida International University, Miami, Florida, United States
[10]Department of Earth and Environment, Florida International University, Miami, Florida, United States
[11]Florida International University and Miami Northwestern Senior High School, Miami, Florida, United States

*Correspondence to*: Caitlyn A. Hall (cahall@arizona.edu) and Sam Illingworth (s.illingworth@napier.ac.uk)

**Abstract**

There is still a significant lack of diversity and equity in geoscience education, even decades after widespread calls for improvement and action. We propose an approach and specific opportunities for educators to improve diversity in geoscience education within higher education: 1) advocating for institutional change, 2) incorporating diverse perspectives and authors in curricula, 3) teaching historical and sociopolitical contexts of geoscience information, 4) connecting geoscience principles to more geographically diverse locations, 5) implementing different communication styles that consider different ways of knowing and learning, and 6) empowering learner transformation and agency.

## 1 Introduction

Geosciences play an essential role in addressing key societal issues, but it is entangled with past and ongoing prejudiced practices, making it an inequitable and exclusive field. Geoscience education that does not interrupt racism and colonialism contributes to the hostile climates and structural problems that hinder diversity in the geosciences (Marín-Spiotta et al., 2020). In this manifesto, we offer six points of reflection that higher education geoscience educators can act upon to recognize and unlearn their biases and to diversify geoscience education (Figure 1). These reflections complement existing resources and communities leading these movements in and beyond geoscience education (e.g., Huntoon and Lane, 2007; Bernard et al., 2018; Gates et al., 2019; Liboiron, 2021; Science Educators for Equity, Diversity, & Social Justice). Furthermore, it serves as a starting conversation point to gather interest and momentum to establish a community-built framework for implementing and strengthening diversity, equity, inclusion, and justice holistically in geoscience education.

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

## 2 Champion Meaningful Transformation

Extracting knowledge from communities without clear reciprocity has historically benefited dominant groups, while excluding and exploiting oppressed communities. Geoscience educators and students should not presume access to knowledge, opportunities, or communities. Communities are not obligated to offer visiting scientists opportunity to engage, and scientists must enter these spaces with respect and humility (la paperson, 2014). Engagement requires building relationships, reciprocity, trust, and accountability (Lewis and Sadler, 2021; Liboiron, 2021). As such, educators must challenge the status quo, commit to action, and develop accountable relationships with communities (Indigenous Action Media, 2014; Powell and Kelly, 2017; Squire, 2019; Jones, 2021; Ali, 2021).

Educators must question institutional factors leading to the lack of diversity in the geosciences and their role in perpetuating them, as detailed by Land Grab Universities. For sustainable change, educational institutions must prioritise the recruitment and retention of educators and learners from marginalised and excluded communities (Carbajal and Hutchinson, 2020; Ormand et al., 2021). Those who benefit from established institutions should champion investing resources in communities and experts that contribute to diversity in geoscience. Advancing diversified geoscience education requires telling the truth about and repairing the legacy of injustices that transferred land and resources to universities, including colonialism and slavery, to build trust and self-determination.

## 3 Diversify Sources

Teaching is research-based as it requires educators to incorporate research output into lessons. Without diversifying one's sources, structural and unconscious bias on the value of specific research sources and types may be perpetuated, leading to low inclusion, a lack of diverse sources, and a system of structural exclusion that proliferates unconscious bias.

By directing users to often-referenced work published in high-impact journals, most search engines decrease the visibility of research published in smaller (e.g., regional) journals. Non-Western authors may rely on local or regional journals due to prohibitive publication costs and lack of accessibility and inclusion in high-profile journals (Jeater, 2018). As a result, publications by Western scientists carrying out research in non-Western regions (with or without local researchers) that are similar to the work of local scientists are cited more widely than their local, non-Western counterparts. This issue is further exacerbated when different languages in regional journals constitute a barrier for incorporation in teaching and learning. While some journals offer discounted publication rates and fee waiver requests, finding and citing work by marginalised researchers and those without ample resources remains a resource-intensive task. SCImago offers a diverse selection of journals and is a great place to start.

Working with students to create an audit of the current reading lists on a geoscience programme is another way to address the lack of diversity in sources (Schucan Bird and Pitman, 2019). When enacting changes, source diversification must centre around author acknowledgement and reciprocity (Keane et al., 2017). Diversifying sources alone, however, could further othering and exploitation. For example, many sustainability efforts extract information from Indigenous practises without

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

considering the complex, holistic origin, and implications of Indigenous science (Tsosie, 2019). Incorporation of Indigenous knowledge into curriculum should align with CARE (Collective Benefit, Authority to Control, Responsibility, Ethics) principles (The Global Indigenous Data Alliance).

## 4 Integrate Historical Context

We can make geoscience education more inclusive by highlighting historical, cultural, and sociopolitical dimensions of geological discoveries. Scientists and marginalised groups are devalued when these aspects are excluded, and the meaningfulness of their contributions is lost. Cartier (2021) and Geocontext raised that few instructors attempt to explain geoscience in historical contexts, like the concept of isostacy and its connection to the British colonial project, the Great Trigonometrical Survey, that aimed to survey the land (Sarkar, 2012). Pandits (Indigenous explorers) brought their intimate knowledge of the land and access to places that the British did not. Pandits contributed significantly to this project yet receive no acknowledgment in Western education. Even today, many scientists downplay local researchers' contributions by excluding them from the author list or only mentioning them in the acknowledgments (Stefanoudis et al., 2021). However, geoscience research is a collaborative endeavour and its culture is shaped by narratives of all collaborators. By excluding them in our education, we are robbing future scientists of the chance to develop and practice more inclusive, diverse, and culturally sensitive approaches to science.

To integrate historical context into our taught curriculum, we must construct narratives that give a more complete representation of how scientific findings take place. One way to do this is by offering socio-scientific courses (e.g., geoscience history, culture, and geoethics) to learners, or by incorporating related topics into introductory courses. This will also benefit interdisciplinary collaborations with humanities and social sciences

## 5 Connect Across Geographies

Geoscience curriculum often focuses on global scales, overlooking local scale context. Most teaching materials emphasize examples from Western regions. For example, many textbooks use the Gulf Stream as an example of ocean-atmosphere dynamics but omit details about the Somali Current and its impact on monsoon behaviour (Schott, 1983). By including diverse geographical contexts, learners can develop a broader understanding of geoscience diversity and variability across the globe, and better connect concepts learned in courses with what is happening in their environment.

Place-based learning introduces different ways of exploring the world, through culturally relevant practices (Johnson et al., 2014; Semken et al., 2017), and can be achieved by diversifying geographic case studies and by using local expertise to understand geoscience concepts. It allows educators to bridge the disconnect between foundational principles, global-theoretical frameworks, and local-practical applications, such that phenomena can be related to observations with greater

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

awareness of how different locations and communities are impacted. This practice amplifies local experts and supports diverse student learning.

## 6 Broaden Pedagogy, Epistemology, & Communication Styles

We can diversify the geoscience curriculum by broadening our approaches to communication, teaching, and epistemology (or ways of knowing). When educators embrace diverse teaching approaches, their students' motivation grows (Tremblay-Wragg, 2019), leading to better student engagement and retention. This also helps educators to create inclusive learning spaces, be respectful of diverse audiences, be culturally sensitive, and support the full inclusion of disabled learners and educators.

We can diversify our communication styles by utilising different strategies in teaching (Mintz, 2020; Illingworth, 2020). This will in turn stimulate learners to diversify how they communicate knowledge. Knowledge sharing (e.g., storytelling, oral histories) by the communities that may not conform to Western teaching practices and tend to be excluded as references and from academia. Academic citations and curriculum should be adapted to bring academic recognition to all ways of knowing, learning, and relating (MacLeod, 2021; Kornei, 2021). This will enable educators to practice place-based learning and honour the knowledge and communities of a more diverse student population.

## 7 Support Transformative Agency in Education

Educators can support transformative, critical science agency by valuing the learning-teaching-knowledge-experience that is grounded in students' current social-emotional needs (Rodriguez, 1998; Durlak et al., 2011). Here, we write these concepts as one hyphenated term to show that they are connected and must be considered holistically. Agency refers to learners' ability to take knowledge and intentionally pursue actions that produce tangible benefits for themselves and/or their communities (Schenkel and Calabrese Barton, 2020). Pedagogy that places Western scientific knowledge as singular, or the ultimate, source of knowledge prevents the development of agency among learners, especially those from historically excluded communities (Smith, 1999; Masta, 2018; Alexiades et al., 2021). However, the weakening of collective and individual agency is not an inevitable outcome of considering different knowledge systems within higher education (Virkkunen, 2006). Different knowledge systems (e.g., Traditional Ecological Knowledge and Western science) can be included and valued in the geoscience curriculum without being broken down to be consistent with one another (Reano and Ridgway, 2015; Smythe, 2017).

Education scholars have begun implementing strategies demonstrating how supporting transformative agency and actions support educational equity (Atwater et al., 2014; Bang et al., 2017; Miller et al., 2020). Reano (2020) describes how a climate change adaptation plan created by the Confederated Tribes and Bands of the Yakama Nation (Yakama Nation) supported the transformative agency of Indigenous students in a communication and policy geoscience module. Holistic educational frameworks support individual learning while serving individuals' community interests.

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

## References

Alexiades, A. V., Haeffner, M. A., Reano, D., Janis, M., Black, J., Sonoda, K., Howard, M., Fiander, C., & Buck, M.: Incorporating Traditional Ecological Knowledge within inclusive pedagogy increases retention and success outcomes of STEM students, The Bulletin of the Ecological Society of America, 102(4): e01924, https://doi.org/10.1002/bes2.1924, 2021.

Ali, H.N., Sheffield, S.L, Bauer, J.E., Caballeo-Gill, R.P., Gasparini, N.M., Libarkin, J., Gonzalez, K.K., Willenbring, J., Amir-Lin, E., Cisneros, J., Desai, D., Erwin, M., Gallant, E., Jeannelle Gomez, K., Keisling, B.A., Mahon, R., Marin-Spiotta, E., Welcome, L., and Schneider, B.: An actionable anti-racism plan for geoscience organizations, Nature Communications, 12, https://doi.org/10.1038/s41467-021-23936-w, 2021.

Atwater, M., Butler, M., & Russell, M. (Eds.): Multicultural science education: Preparing teachers for equity and social justice, Springer, New York, United States, 2014.

Bang, M., Brown, B., Calabrese Barton, A., Rosebery, A., & Warren, B.: Toward more equitable learning in science: Expanding relationships among students, teachers, and science practices, in: Helping students make sense of the world using next generation science and engineering practices, edited by: C. V. Schwarz, C. Passmore, & B. J. Reiser, 33-58, National Science Teachers Association (NSTA) Press, Arlington, United States, 2017

Bernard, R.E., Cooperdock, E.H.G.: No progress on diversity in 40 years. Nature Geosci., 11, 292–295, https://doi.org/10.1038/s41561-018-0116-6, 2018.

Carbajal, I.G., and Atchinson, C.L.: An investigation of accessible and inclusive instructional field practices in US geoscience departments, Advances in Geosciences, 53, 53-63, https://doi.org/10.5194/adgeo-53-53-2020, 2020.

Cartier, K.M.S.: Teaching Geoscience History in Context, Eos, https://eos.org/articles/teaching-geoscience-history-in-context, 2021.

Durlak, J. A., Weissberg, R. P., Dymnicki, A. B., Taylor, R. D., & Schellinger, K.: The impact of enhancing students' social and emotional learning: A meta-analysis of school-based universal interventions, Child Development, 82, 405-432, https://doi.org/10.1111/j.1467-8624.2010.01564.x, 2011.

Gates, A.E., McNeal, K., Riggs, E., Sullivan, S., and Dalbotten, D.: New developments in diversity and inclusiveness in geosciences, Journal of Geoscience Education, 67:4, 285-286, https://doi.org/10.1080/10899995.2019.1671713, 2019.

GeoContext.: https://geo-context.github.io/, last access: 11 February 2022.

Global Indigenous Data Alliance.: https://www.gida-global.org/care, last access: 11 February 2022.

Huntoon, J.E., and Lane, M.J.: Diversity in the Geosciences and Successful Strategies for Increasing Diversity, Journal of Geoscience Education, 55(6), 447-457, https://doi.org/10.5408/1089-9995-55.6.447, 2007.

Illingworth, S.: Creative communication – using poetry and games to generate dialogue between scientists and nonscientists, FEBS Letters, 594(15), https://doi.org/10.1002/1873-3468.13891, 2020.

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

Jeater, D.: Academic Standards or Academic Imperialism? Zimbabwean perceptions of hegemonic power in the global construction of knowledge, African Studies Review, 61(2), 8-27, https://doi.org/10.1017/asr.2017.132, 2018.

Jones, J. C.: We need accomplices, not allies in the fight for an equitable geoscience. AGU Advances, 2(3), e2021AV000482, https://doi.org/10.1029/2021AV000482, 2021.

Johnson, A. N., Sievert, R., Durglo, Sr., M., Finley, V., Adams, L., Hofmann, M. H.: Indigenous Knowledge and Geoscience on the Flathead Indian Reservation, Northwest Montana: Implications for Place-Based and Culturally Congruent Education, J. of Geo. Edu., 62, 187 - 202, https://doi.org/10.5408/12-393.1, 2014.

Keane, M., Khupe, C., & Seehawer, M.: Decolonising methodology: Who benefits from indigenous knowledge research?, Educational Research for social change, 6(1), 12-24, http://dx.doi.org/10.17159/2221-4070/2017/v6i1a2, 2017.

Kornei, K.: Academic citations evolve to include Indigenous oral teachings, Eos, 102, https://doi.org/10.1029/2021EO210595, 2021.

la paperson: A ghetto land pedagogy: an antidote for settler environmentalism, Environmental Education Research, 20(1), https://doi.org/10.1080/13504622.2013.865115, 2014.

Land Grab Universities.: https://www.landgrabu.org/, last access: 11 February 2022.

Liboiron, M.: Decolonizing geoscience requires more than equity and inclusion. Nat. Geosci. 14, 876–877,. https://doi.org/10.1038/s41561-021-00861-7, 2021.

MacLeod, L.: More Than Personal Communication: Templates For Citing Indigenous Elders and Knowledge Keepers. KULA: Knowledge Creation, Dissemination, and Preservation Studies 5(1), https://doi.org/10.18357/kula.135, 2021.

Masta, S.: What the grandfathers taught me: Lessons for an Indian country researcher. The Qualitative Report, 23 (4), 841-852, https://doi.org/10.46743/2160-3715/2018.3254, 2018.

Miller, R., Liu, K., & Ball, A. F.: Critical counter-narrative as transformative methodology for educational equity. Review of Research in Education, 44, 269-300, https://doi.org/10.3102/0091732X20908501, 2020.

Mintz, S.: Pedagogy and Course Design Need to Change. Here's How., Inside Higher Ed, https://www.insidehighered.com/blogs/higher-ed-gamma/pedagogy-and-course-design-need-change-here%E2%80%99s-how, last access: 11 February 2022.

Ormand, C.J., Macdonald, R.H., Hodder, J., Bragg, D.D., Baer, E.M.D., and Eddy, P.: Making departments diverse, equitable, and inclusive: Engaging colleagues in departmental transformation through discussion groups committed to action, J. of Geoscience Education, https://doi.org/10.1080/10899995.2021.1989980, 2021.

Powell, J., & Kelly, A.: Accomplices in the academy in the age of Black Lives Matter. Journal of Critical Thought and Praxis, 6(2), https://www.iastatedigitalpress.com/jctp/article/id/551/, 2017.

Reano, D.: Using Indigenous research frameworks in the multiple contexts of research, teaching, mentoring, and leading. The Qualitative Report, 25(11), 3902-3926, https://doi.org/10.46743/2160-3715/2020.4317, 2020.

Reano, D. & Ridgway, K. D.: Connecting geology and Native American culture on the reservation of Acoma Pueblo, New Mexico. GSA Today, 25 (8), 26-28, https://doi.org/10.1130/GSAT-G235GW.1, 2015.

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

Rodriguez, A.: Strategies for counterresistance: Toward sociotransformative constructivism and learning to teach science for diversity and for understanding. Journal of Research in Science Teaching, 35 (6), 589-622, https://doi.org/10.1002/(SICI)1098-2736(199808)35:6%3C589::AID-TEA2%3E3.0.CO;2-I, 1998.

Sarkar, O.: The Great Trigonometrical Survey: Histories of Mapping 1790–1850, ETraverse The Indian Journal of Spatial Science, 3(1), 1-6, https://www.academia.edu/8906484/The_Great_Trigonometrical_Survey_Histories_Of_Mapping_1790_185, 2012.

Schenkel, K., & Calabrese Barton, A.: Critical science agency and power hierarchies: Restructuring power within group to address injustice beyond them, Science Education, 104(3), 1-30, https://doi.org/10.1002/sce.21564, 2020.

Schott, F.: Monsoon response of the Somali Current and associated upwelling. Progress in Oceanography, 12(3), 357-381, https://doi.org/10.1016/0079-6611(83)90014-9, 1983.

Schucan Bird, K., and Pitman, L.: How diverse is your reading list? Exploring issues of representation and decolonisation in the UK, High Educ, 79, 903–920, https://doi.org/10.1007/s10734-019-00446-9, 2020.

Science Educators for Equity, Diversity, and Social Justice.: https://sefedasj.wildapricot.org/, last access: 14 February 2022.

SCImago.: https://www.scimagojr.com/journalrank.php, last access: 11 February 2022.

Semken, S., Geraghty Ward, E., Moosavi, S., & Chinn, P.W.U.: Place-Based Education in Geoscience: Theory, Research, Practice, and Assessment, Journal of Geoscience Education, 65:4, 542-562, https://doi.org/10.5408/17-276.1, 2017.

Smith, L. T.: Decolonizing Methodologies: Research and Indigenous Peoples, Zed Books, London, United Kingdom, 1999.

Smythe, W., Hugo, R., & McAllister, S. M.: Incorporation of Traditional Knowledge into geoscience education: An effective method of Native American instruction. Journal of Sustainability Education, 14, http://www.susted.com/wordpress/content/incorporation-of-traditional-knowledge-into-geoscience-education-an-effective-method-of-native-american-instruction_2017_06/, 2017.

Squire, D. D.: Ending allies through the eradication of the ally (industrial) complex, in: Rethinking LGBTQIA Students and Collegiate Contexts, edited by: Zamani-Gallagher, E.M., Dibya Choudhuri, D., and Taylor, J.L., Routledge, London, United Kingdom, 186-203, 2019.

Stefanoudis, P.V., Licuanan, W.Y., Morrison, T.H., Talma, S., Veitayaki, J., and Woodall, L.C.: Turning the tide of parachute science, Current Biology, 31(4), R184-R185, https://doi.org/10.1016/j.cub.2021.01.029, 2021.

Tremblay-Wragg, E., Raby, C., Ménard, L., and Plante, I.: The use of diversified teaching strategies by four university teachers: what contribution to their students' learning motivation?, Teaching in Higher Education, 26:1, 97-114, DOI: 10.1080/13562517.2019.1636221, 2021.

Tsosie, R.: Indigenous Sustainability and Resilience to Climate Extremes: Traditional Knowledge and the Systems of Survival, Connecticut Law Review, 407, https://opencommons.uconn.edu/law_review/40, 2019.

Virkkunen, J.: Dilemmas in building shared transformative agency, Activités [En ligne], 3-1, https://doi.org/10.4000/activites.1850, 2006.

https://doi.org/10.5194/egusphere-2022-116
Preprint. Discussion started: 19 April 2022
© Author(s) 2022. CC BY 4.0 License.

Yakama Nation.: Climate adaptation plan for the territories of the Yakama Nation Version 1, https://critfc.org/fish-and-watersheds/climate/, last access: 14 February, 2022.

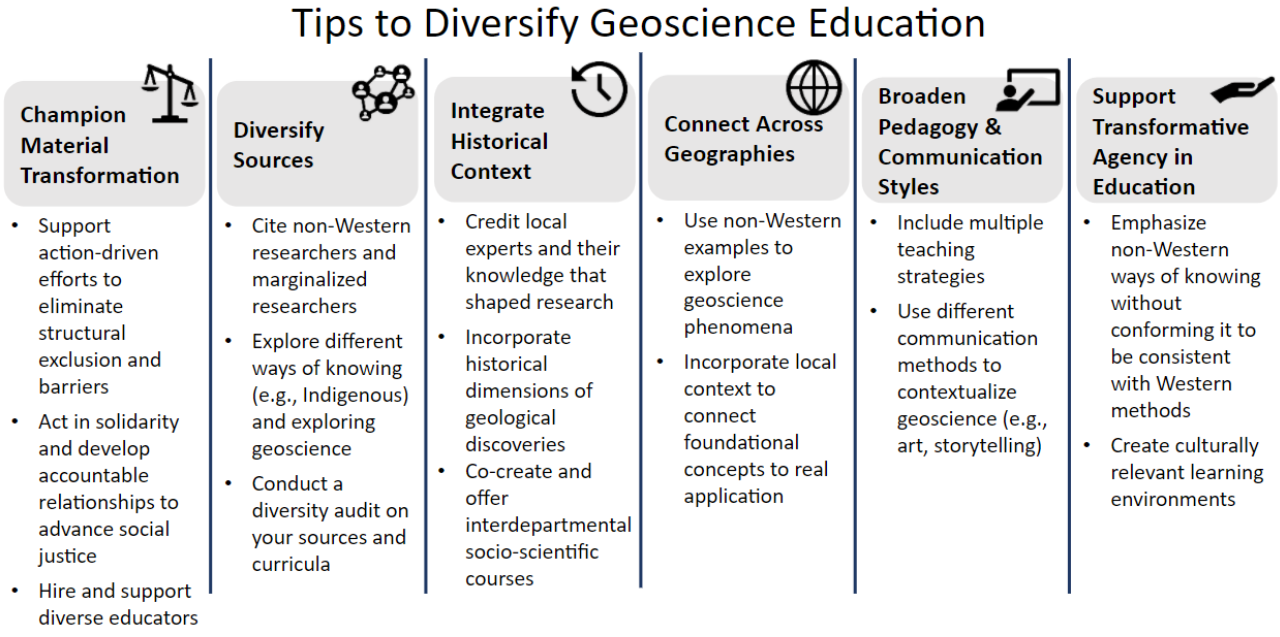


**Figure 1: Summarised recommendations for educators to diversify their geoscience curriculum and education.**