Pathways to Diversity and Inclusion in Geoscience: Challenges and Opportunities

COREY GARZA

DEPARTMENT OF MARINE SCIENCE

CALIFORNIA STATE UNIVERSITY, MONTEREY BAY

Diversity Data for the Geosciences

- Recent NSF statistics: Approximately **8%** of graduate students are underrepresented (NSF 2018).
- Biological Sciences slightly higher percentage, **18%**.
- Whole number comparison: **1303** total underrepresented Geoscience, **9520** in the Biological Sciences.

No progress on diversity in 40 years

Ethnic and racial diversity are extremely low among United States citizens and permanent residents who earned doctorates in earth, atmospheric and ocean sciences. Worse, there has been little to no improvement over the past four decades.

Rachel E. Bernard and Emily H. G. Cooperdock

Nature Geoscience
2018

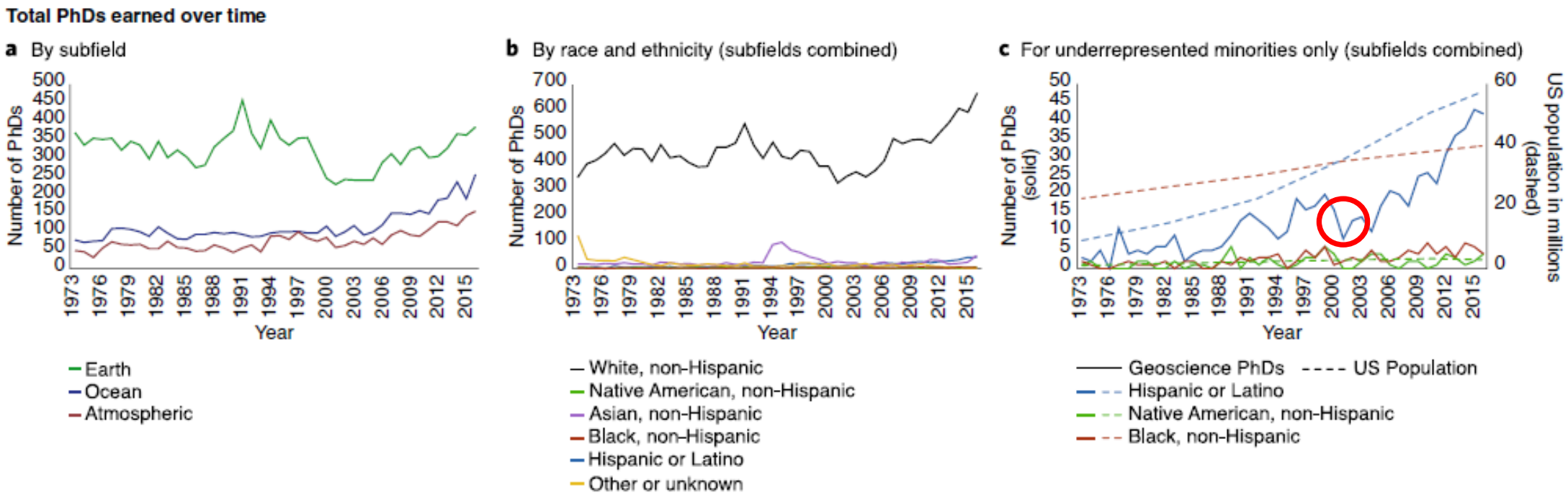

Fig. 1 | PhDs earned by US citizens and permanent residents between 1973 and 2016. a, The total number of PhDs for all races, ethnicities and genders combined have fluctuated around 350 for the earth sciences, but have taken an upward turn from a stable base level in the last decade or so for ocean and atmospheric sciences. **b**, The largest race/ethnicity category by far is the White non-Hispanic PhD group. **c**, Focusing on what the NSF considers to be underrepresented minorities (that is, excluding White non-Hispanics and Asian non-Hispanics), and comparing with the increasing share of these groups in the US population (measured by decadal census and 2016 estimate), it becomes clear that gains in Hispanic or Latino PhDs largely reflect an increase in the relevant population in the US, and that there are no gains in PhDs earned among the other underrepresented groups. Data in **a**–**c** run from 1973 to 2016.

Opportunities for Improving DEI In Geoscience

- Student Engagement/Inclusion
- Resource Allocation
- Leadership Development

Low Student Diversity: Causes

- Historic overemphasis of certain fields (e.g. biomedical).
- Unclear understanding by students.
- Ineffective messaging and engagement, particularly at the early undergraduate stage.

- Lack of community and belonging.

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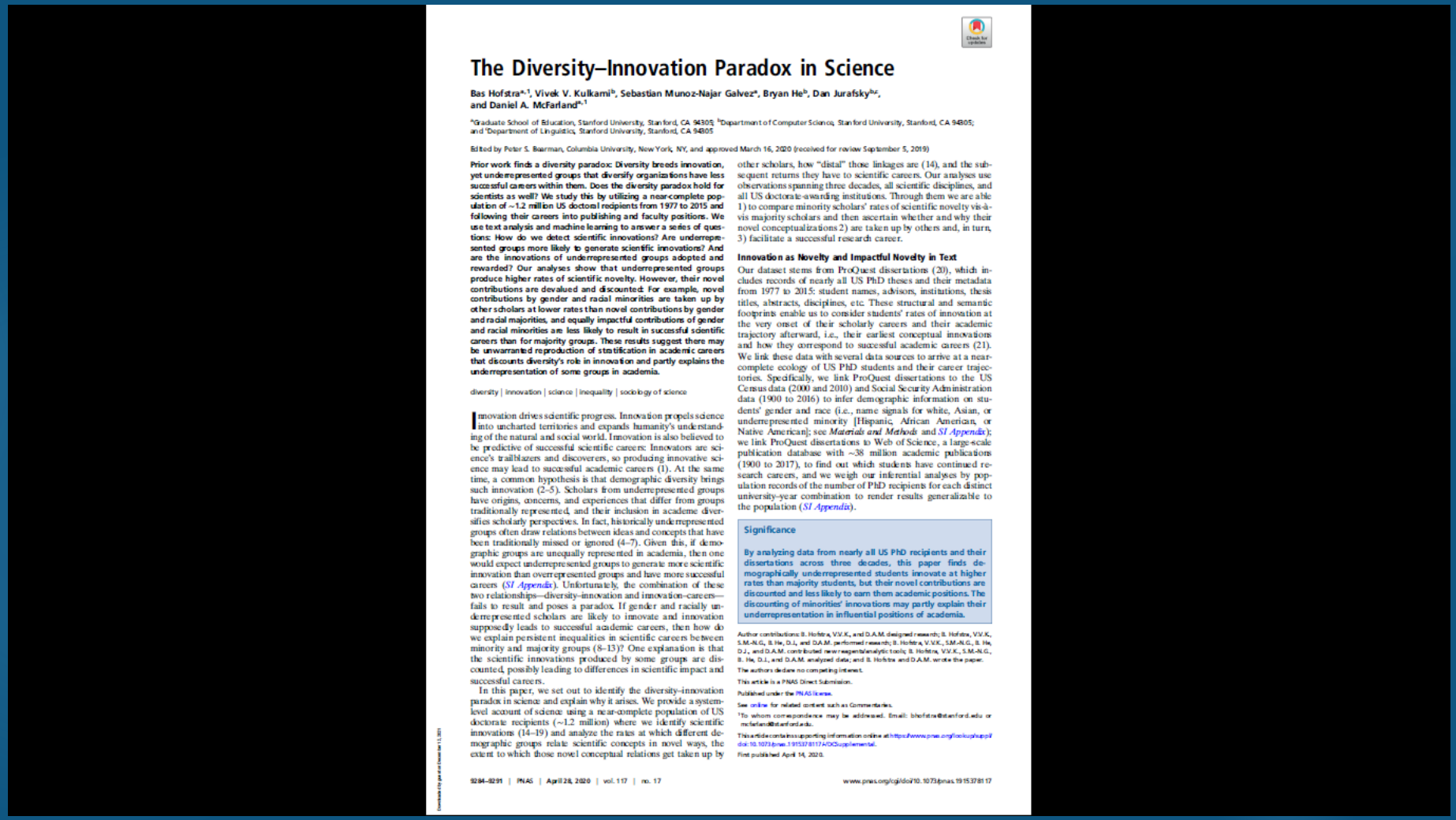

The Diversity–Innovation Paradox in Science

Bas Hofstra[a,1], Vivek V. Kulkarni[b], Sebastian Munoz-Najar Galvez[a], Bryan He[b], Dan Jurafsky[b,c], and Daniel A. McFarland[a,1]

[a]Graduate School of Education, Stanford University, Stanford, CA 94305; [b]Department of Computer Science, Stanford University, Stanford, CA 94305; and [c]Department of Linguistics, Stanford University, Stanford, CA 94305

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Prior work finds a diversity paradox: Diversity breeds innovation, yet underrepresented groups that diversify organizations have less successful careers within them. Does the diversity paradox hold for scientists as well? We study this by utilizing a near-complete population of ∼1.2 million US doctoral recipients from 1977 to 2015 and following their careers into publishing and faculty positions. We use text analysis and machine learning to answer a series of questions: How do we detect scientific innovations? Are underrepresented groups more likely to generate scientific innovations? And are the innovations of underrepresented groups adopted and rewarded? Our analyses show that underrepresented groups produce higher rates of scientific novelty. However, their novel contributions are devalued and discounted: For example, novel contributions by gender and racial minorities are taken up by other scholars at lower rates than novel contributions by gender and racial majorities, and equally impactful contributions of gender and racial minorities are less likely to result in successful scientific careers than for majority groups. These results suggest there may be unwarranted reproduction of stratification in academic careers that discounts diversity's role in innovation and partly explains the underrepresentation of some groups in academia.

diversity | innovation | science | inequality | sociology of science

Innovation drives scientific progress. Innovation propels science into uncharted territories and expands humanity's understanding of the natural and social world. Innovation is also believed to be predictive of successful scientific careers: Innovators are science's trailblazers and discoverers, so producing innovative science may lead to successful academic careers (1). At the same time, a common hypothesis is that demographic diversity brings such innovation (2–5). Scholars from underrepresented groups have origins, concerns, and experiences that differ from groups traditionally represented, and their inclusion in academe diversifies scholarly perspectives. In fact, historically underrepresented groups often draw relations between ideas and concepts that have been traditionally missed or ignored (4–7). Given this, if demographic groups are unequally represented in academia, then one would expect underrepresented groups to generate more scientific innovation than overrepresented groups and have more successful careers (*SI Appendix*). Unfortunately, the combination of these two relationships—diversity–innovation and innovation–careers—fails to result and poses a paradox. If gender and racially underrepresented scholars are likely to innovate and innovation supposedly leads to successful academic careers, then how do we explain persistent inequalities in scientific careers between minority and majority groups (8–13)? One explanation is that the scientific innovations produced by some groups are discounted, possibly leading to differences in scientific impact and successful careers.

In this paper, we set out to identify the diversity-innovation paradox in science and explain why it arises. We provide a system-level account of science using a near-complete population of US doctorate recipients (∼1.2 million) where we identify scientific innovations (14–19) and analyze the rates at which different demographic groups relate scientific concepts in novel ways, the extent to which those novel conceptual relations get taken up by other scholars, how "distal" those linkages are (14), and the subsequent returns they have to scientific careers. Our analyses use observations spanning three decades, all scientific disciplines, and all US doctorate-awarding institutions. Through them we are able 1) to compare minority scholars' rates of scientific novelty vis-à-vis majority scholars and then ascertain whether and why their novel conceptualizations 2) are taken up by others and, in turn, 3) facilitate a successful research career.

Innovation as Novelty and Impactful Novelty in Text

Our dataset stems from ProQuest dissertations (20), which includes records of nearly all US PhD theses and their metadata from 1977 to 2015: student names, advisors, institutions, thesis titles, abstracts, disciplines, etc. These structural and semantic footprints enable us to consider students' rates of innovation at the very onset of their scholarly careers and their academic trajectory afterward, i.e., their earliest conceptual innovations and how they correspond to successful academic careers (21). We link these data with several data sources to arrive at a near-complete ecology of US PhD students and their career trajectories. Specifically, we link ProQuest dissertations to the US Census data (2000 and 2010) and Social Security Administration data (1900 to 2016) to infer demographic information on students' gender and race (i.e., name signals for white, Asian, or underrepresented minority [Hispanic, African American, or Native American]; see *Materials and Methods* and *SI Appendix*); we link ProQuest dissertations to Web of Science, a large-scale publication database with ∼38 million academic publications (1900 to 2017), to find out which students have continued research careers, and we weigh our inferential analyses by population records of the number of PhD recipients for each distinct university-year combination to render results generalizable to the population (*SI Appendix*).

Significance

By analyzing data from nearly all US PhD recipients and their dissertations across three decades, this paper finds demographically underrepresented students innovate at higher rates than majority students, but their novel contributions are discounted and less likely to earn them academic positions. The discounting of minorities' innovations may partly explain their underrepresentation in influential positions of academia.

Author contributions: B. Hofstra, V.V.K., and D.A.M. designed research; B. Hofstra, V.V.K., S.M.-N.G., B. He, D.J., and D.A.M. performed research; B. Hofstra, V.V.K., S.M.-N.G., B. He, D.J., and D.A.M. contributed new reagents/analytic tools; B. Hofstra, V.V.K., S.M.-N.G., B. He, D.J., and D.A.M. analyzed data; and B. Hofstra and D.A.M. wrote the paper.

The authors declare no competing interest.

This article is a PNAS Direct Submission.

See online for related content such as Commentaries.

[1]To whom correspondence may be addressed. Email: bhofstra@stanford.edu or mcfarlan@stanford.edu.

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Hofstra et al. 2020

Graduate students from minority backgrounds innovated at higher rate but were rewarded less often.

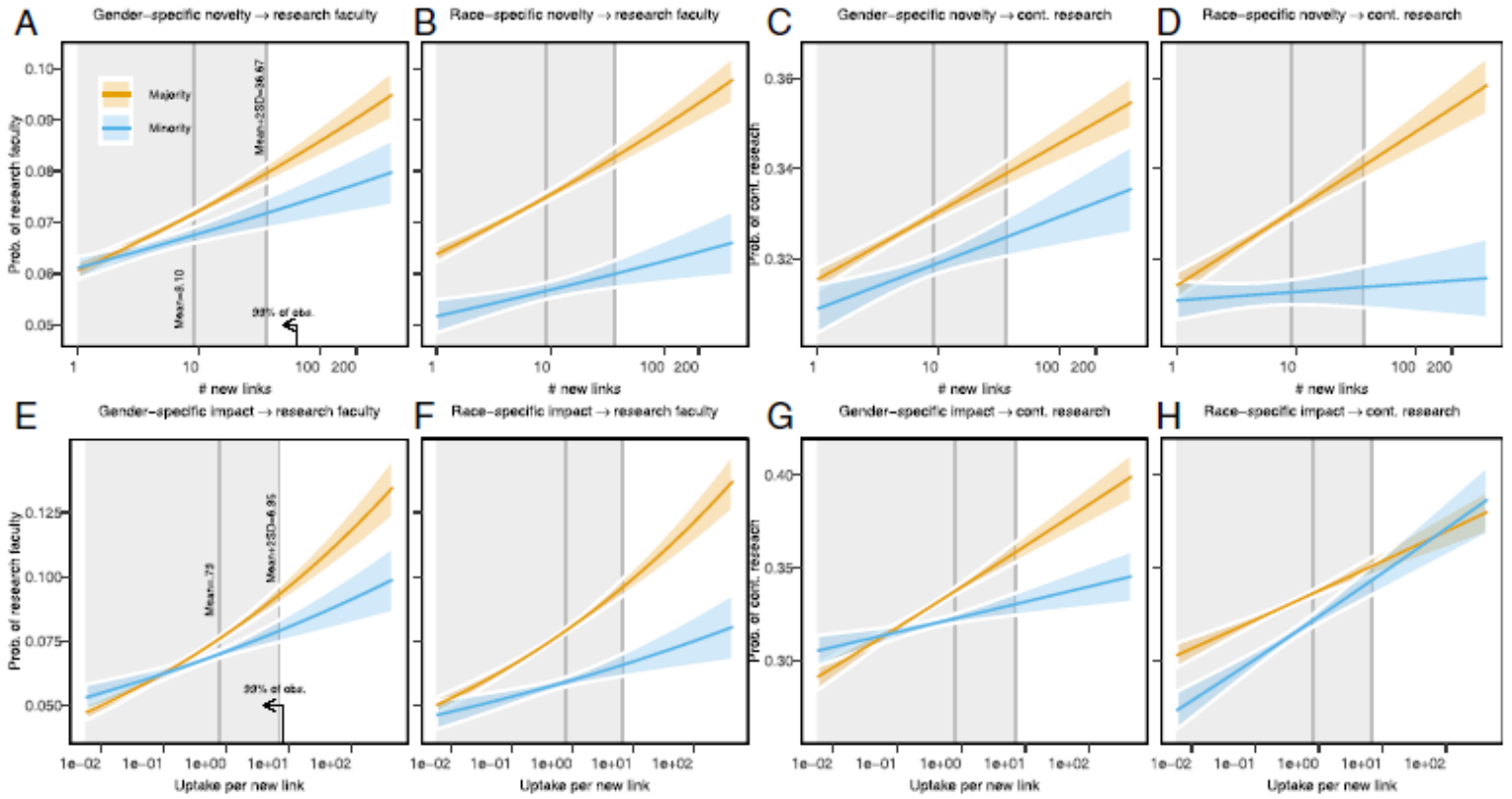
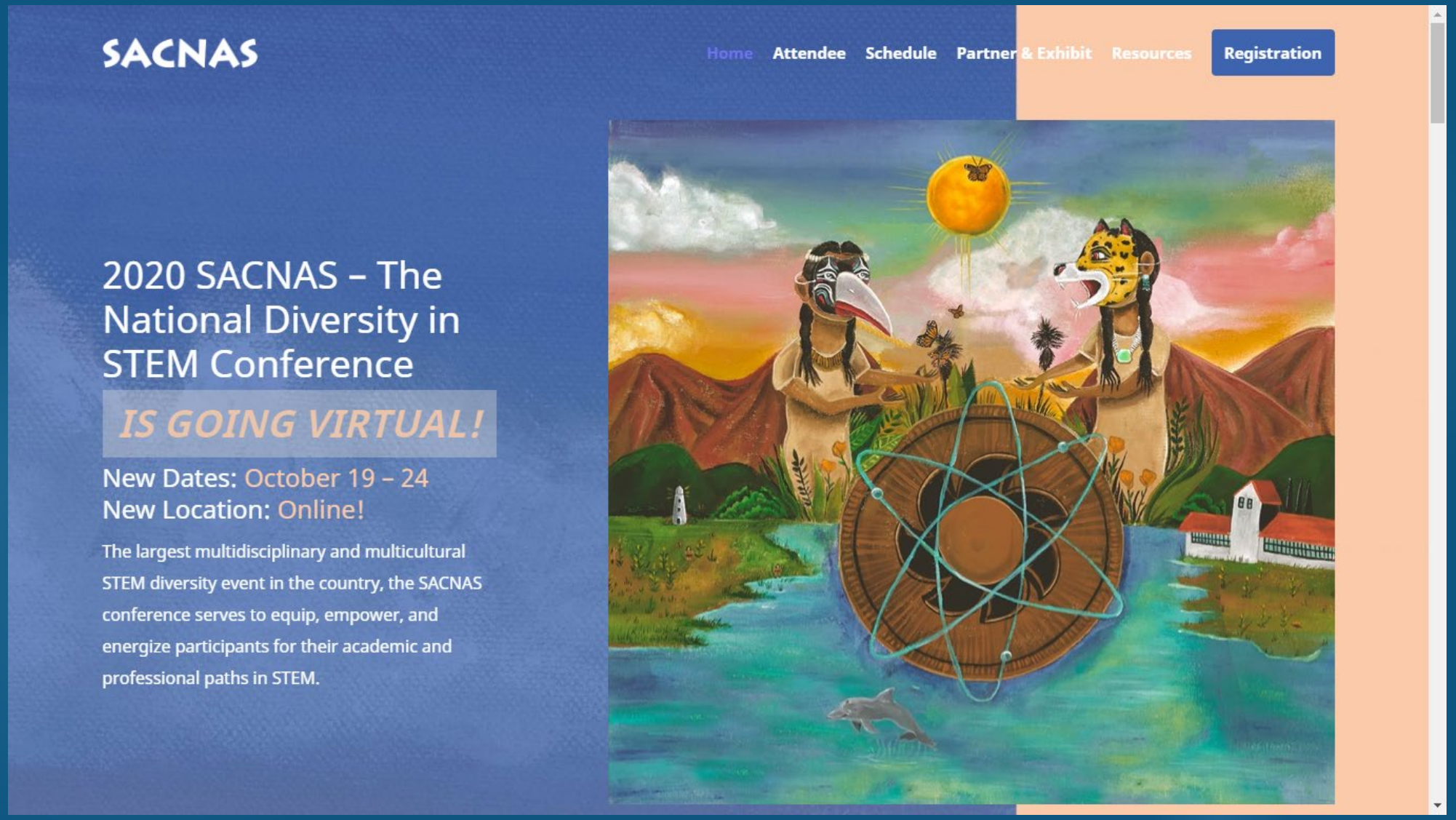


Fig. 4. The novelty and impactful novelty minorities introduce have discounted returns for their careers. (*A–H*) Each of the observed patterns holds with and without controlling for distal novelty. (*A–D*) Correlation of gender- and race-specific novelty with becoming research faculty or continued researcher (n = 805,236). As novelty increases, the probabilities of becoming faculty (for gender and race) and continuing research (for race) have diminished returns for minorities. For instance, a 2SD increase from the median level of novelty (# new links) increases the relative difference in probability to become research faculty between gender minorities and majorities from 3.5 to 9.5%. (*E–H*) Correlation of gender- and race-specific impactful novelty with becoming research faculty and a continued researcher (when novelty is nonzero, n = 628,738). With increasing impactful novelty, the probabilities of becoming faculty (for gender and race) and continuing research (for gender) start to diverge at the expense of the career chances of minorities. For instance, a 2SD increase from the median of impactful novelty (uptake per new link) increases the relative difference in probability of becoming research faculty between gender minorities and majorities from 4.3 to 15%.

SACNAS: Student Engagement



SACNAS Activities

Geoscience Row

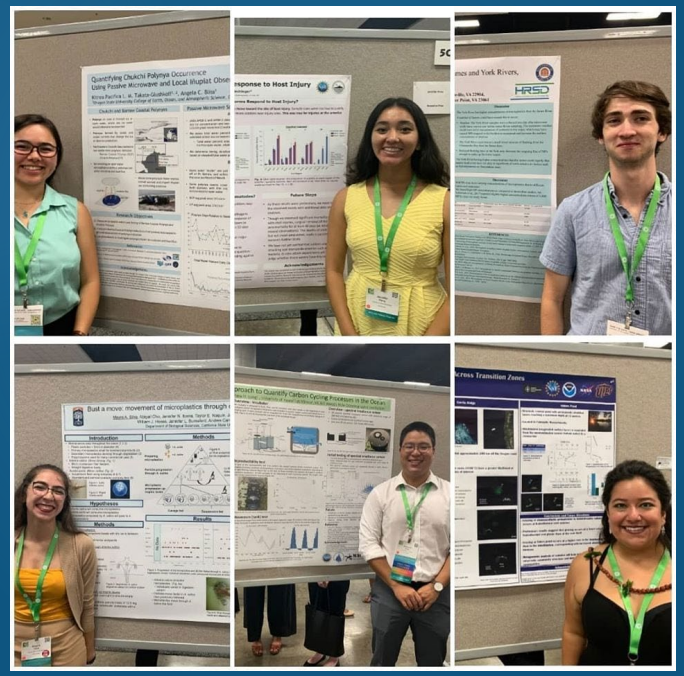
Geoscience Talks

Student Posters

Professional Development Sessions

SACNAS Geo-Futures

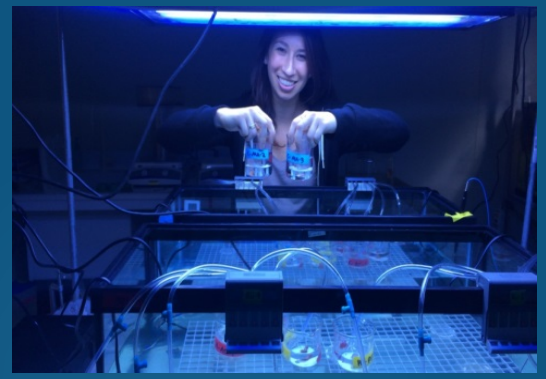
- Provides funding for students who have participated in Geoscience REUs or similar programs.
- Provides pre-conference preparation for students and mentors.
- Matches students up with Geoscience mentors at conference.
- Conference based sessions attached to Geo-Futures.
- Post-conference student support.



NSF

NOAA Cooperative Science Center: Resource Allocation

- Funded by NOAA's Educational Partnership Program (EPP).
- Designed to increase the number and diversity of students who attend minority serving institutions and graduate with STEM degrees.
- Four new centers established in 2016.
- Each center awarded $15.5 million over five years.



Center for Earth Systems Science and Remote Sensing Technology

Center for Coastal and Marine Ecosystems*

Living Marine Systems Cooperative Science Center

Center for Atmospheric Sciences and Meteorology

NOAA Center for Coastal and Marine Ecosystems (CCME)

- A partnership between six minority serving institutions.
- Florida A&M University (Lead Institution, Larry Robinson, Ph.D.)
- Bethune-Cookman University (Florida, Hyun Jung Cho, Ph.D)
- California State University, Monterey Bay (Corey Garza, Ph.D.)
- Jackson State University (Mississippi, Timothy Turner, Ph.D.)
- Texas A&M University, Corpus Christi (Richard McLaughlin, Ph.D.)
- University of Texas, Rio Grande Valley (David Hicks, Ph.D.)

NOAA CCME Annual Meeting

NOAA Center for Coastal and Marine Ecosystems

- Train graduate and undergraduates in NOAA relevant science.
- Program designed to train a diverse future workforce for NOAA.
- Students and faculty engage in social science research as part of the program.
- Supports development of research capacity (Garza 2021).

Diverse Ocean Science Community through Collaboration (DOCC)

- New NSF program designed to reframe the research relationship between R1 and MSIs within the grant development process.
- Provides training for faculty and staff at both MSI and R1 institutions.
- Faculty from R1 and MSI institutions brought together in an IDEAS lab style event.
- Aims to facilitate the development of novel research ideas that may not develop outside of the interactions set within this program.

NSF GOLD
(Geo Opportunities for Leadership in Diversity)
https://cpaess.ucar.edu/gold

ASPIRE
(Active Societal Participation in Research and Education)

- Uses place-based science as a vehicle to bridge underserved communities and the Geosciences.
- Uses the working group model as a forum for linking underserved communities with the geosciences.
- Operates as a virtual center that funds and facilitates working groups (resource allocation).

ASPIRE Case Study: Sumida Farms, Hawaii (PI: Dr. Jennifer Engels, University of Hawaii)

- Collaborative research partnership with family-owned farm on O'ahu.
- Researching issues around changes in water quality and saltwater intrusion.
- Blending geoscience approaches with traditional Hawaiian knowledge on changes in local water quality.
- Research is being used to improve water quality and transferred to local farms in Hawaii.

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RESEARCH ARTICLE

Collaborative research to support urban agriculture in the face of change: The case of the Sumida watercress farm on O'ahu

Jennifer L. Engels, Sheree Watson, Henrietta Dulai, Kimberly M. Burnett, Christopher A. Wada, 'Ano'ilani Aga, Nathan DeMaagd, John McHugh, Barbara Sumida †, Leah L. Bremer

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Abstract

Introduction

Methods

Abstract

As urban areas expand around the world, there are growing efforts to restore and protect natural and agricultural systems for the multitude of ecosystem services they provide to urban

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ORIGINAL RESEARCH ARTICLE

Front. Water, 09 July 2020 | https://doi.org/10.3389/frwa.2020.00014

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Incorporating Historical Spring Discharge Protection Into Sustainable Groundwater Management: A Case Study From Pearl Harbor Aquifer, Hawai'i

Kimberly M. Burnett[1,2*], Ahmed S. Elshall[2,3], Christopher A. Wada[1,2], Aida Arik[4], Aly El-Kadi[2,5], Clifford I. Voss[2], Jade M. S. Delevaux[6] and Leah L. Bremer[1,2]

[1]University of Hawai'i Economic Research Organization, University of Hawai'i at Mānoa, Honolulu, HI, United States

[2]Water Resources Research Center, University of Hawai'i at Mānoa, Honolulu, HI, United States

EDITED BY

Roman Seidl

Leibniz University Hannover, Germany

REVIEWED BY

Lindsey M. Yasarer

Agricultural Research Service, United States Department of Agriculture, United States

Yonghong Hao

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DEI: Reframing Your Science Identity

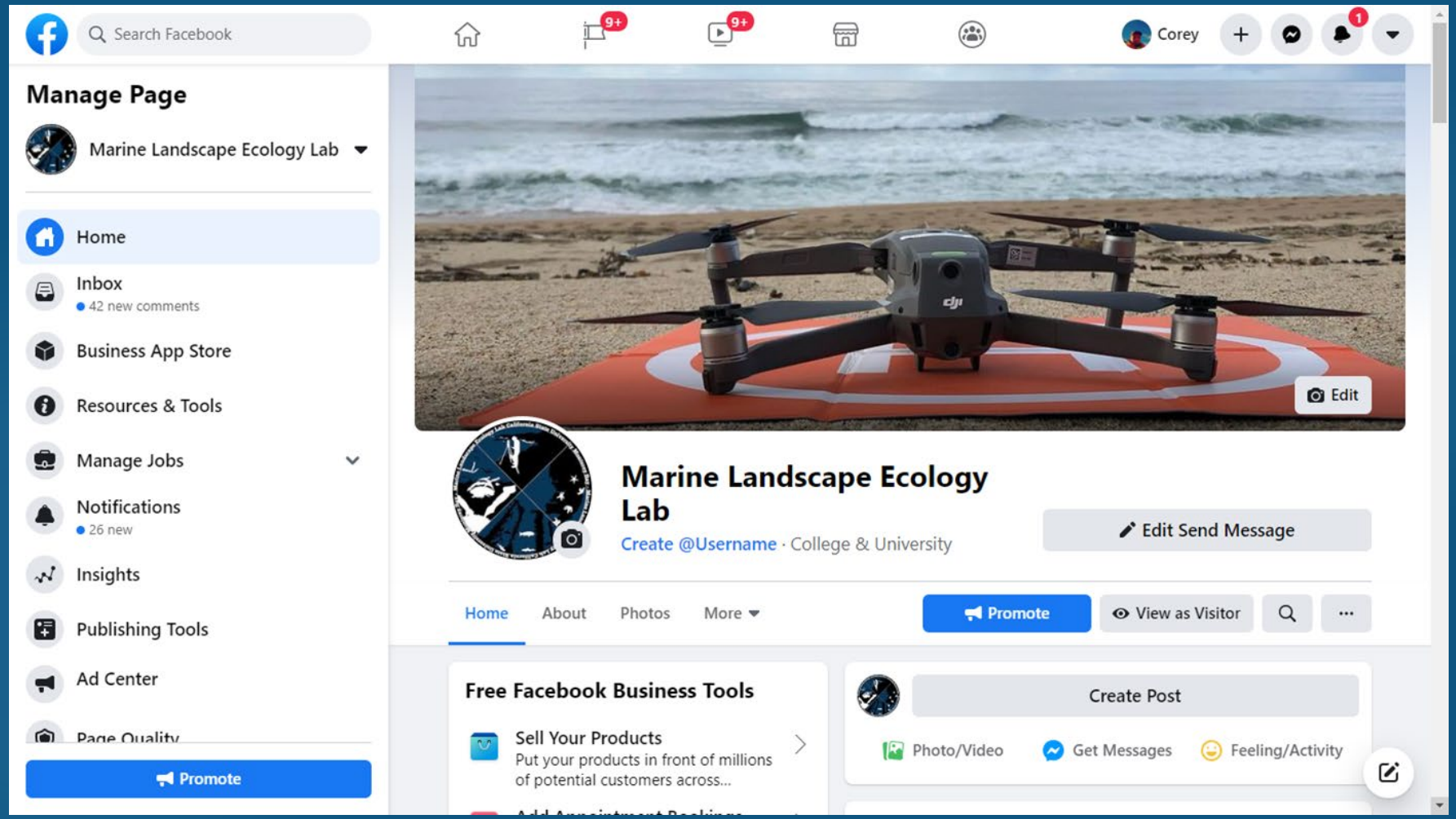
- "I'm not an educator, I'm a researcher".

- Improving DEI in STEM requires re-visiting our personal definitions of a scientist.

Josh Kohut, Rutgers University

Combining Research and DEI

- Engaging in DEI work does not mean sacrificing your research.



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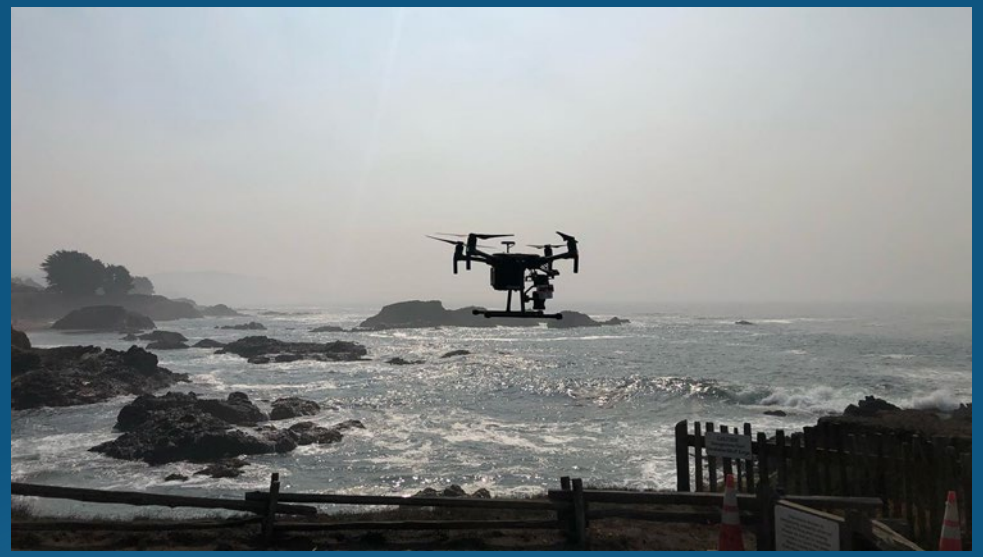
Combining Research and DEI



Marine Landscape Ecology Lab California State University Monterey Bay - Marine Landscape Ecology Lab California State University Monterey Bay -

Marine Tech Research and Training

Taylor Eddy (Costanoan-Rumsen)
M.Sc. Marine Science 2021
USGS Research Specialist
REU Student Participant

Dr. Michael Navarro
NSF Ocean Science Postdoctoral Fellow
Assistant Professor of Fisheries, University of Alaska
SACNAS Student Participant

Engaging Diverse Audiences in Ocean Science

- NOAA sponsored drone training with Bethune-Cookman University, Florida A&M, Jackson State University, Texas A&M Corpus-Christi and University of Texas Rio Grande Valley.

Operationalize DEI

- Allocate reasonable funding/staffing so that DEI efforts are well supported.
- Engage collaborators who have a history of working on DEI.
- Include active strategies for your DEI work (ex. Don't assume being affiliated with someone from an MSI will automatically strengthen your DEI work).
- Make DEI collaborators an integrated part of the research team.
- Revisit how DEI work is rewarded within your own organizations.

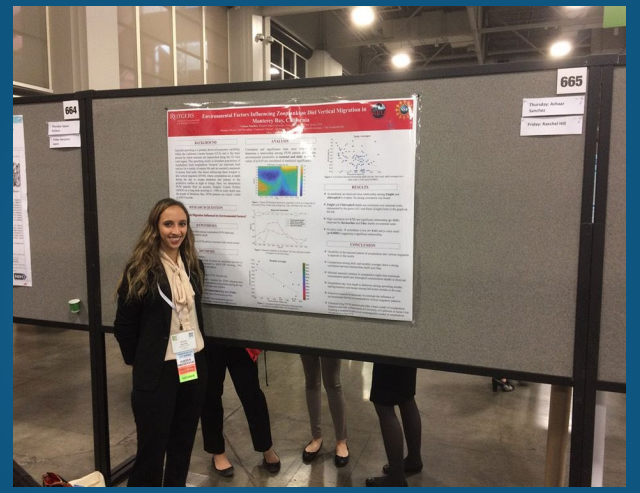
ARIS

Advancing Research Impacts in Society

SACNAS Conversations with Scientists

DEI: Who to include?

- DEI can focus on more than just race, ethnicity and gender.
- Consider work with additional groups that are underrepresented in STEM.
- U.S. Veterans.
- Individuals with disabilities.
- LGBTQ+ groups.
- Consider broader societal impacts.



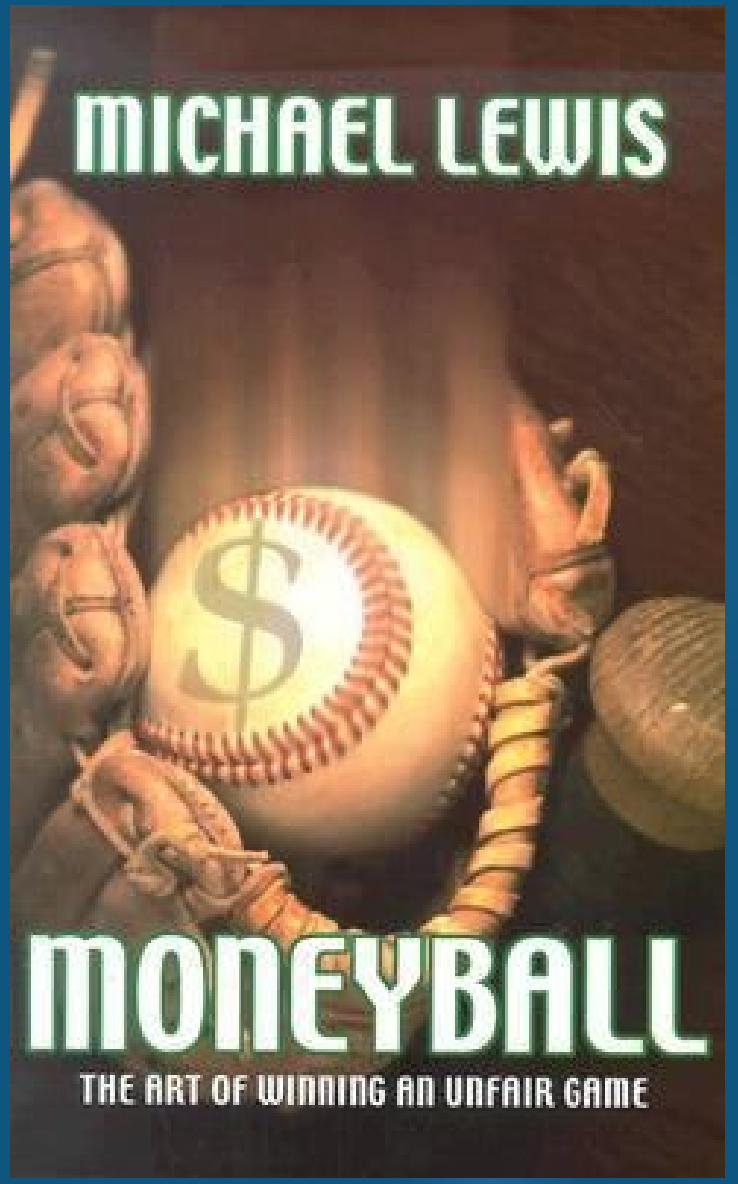
Ashaar Sanchez, USAF Veteran, CSUMB REU Alumna, M.Sc. Student Coastal Carolina University

iAGD
International Association for Geoscience Diversity

Specializes in improving access to geoscience for those with disabilities.

A "Moneyball Approach"

- Approach taken by the Oakland A's to field a competitive team.
- Used to account for lack or resources.
- Cultivate talents that are undervalued by large market teams.
- Resulted in a new way of assessing talent and fielding competitive teams.



Why DEI in Geoscience?

- Improves the diversity of those who engage in STEM.
- Helps bring new ideas and perspectives to our fields.
- Can result in new ways of conducting research.

Thank You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