Journal of Geoscience Education

ISSN: 1089-9995 (Print) 2158-1428 (Online) Journal homepage: https://www.tandfonline.com/loi/ujge20

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To cite this article: Allison Mattheis, Megan Murphy & Erika Marin-Spiotta (2019): Examining intersectionality and inclusivity in geosciences education research: A synthesis of the literature 2008–2018, Journal of Geoscience Education

To link to this article: https://doi.org/10.1080/10899995.2019.1656522

Published online: 30 Sep 2019.

JOURNAL OF GEOSCIENCE EDUCATION
https://doi.org/10.1080/10899995.2019.1656522

Examining intersectionality and inclusivity in geosciences education research: A synthesis of the literature 2008–2018

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ABSTRACT

This article reviews geoscience education research published since the December 2007 "Broadening Participation" issue of the *Journal of Geoscience Education* to examine how research in the field has taken up—or not—calls for greater inclusivity. We also applied recent calls to actively confront and lessen reports of discrimination and harassment in the sciences and looked for evidence of how these goals are included in geoscience education research. This synthesis of the extant literature in geoscience education research was guided by a framework that draws from the concept of intersectionality (Collins, 2015; Crenshaw, 1991) and interventions that can build learning environments that provide physical and psychological safety for diverse students, educators, and field professionals synthesized by a 2018 report from the National Academies of Science, Engineering, and Medicine. We identified three primary themes in the literature reviewed and illustrate these with examples from published articles: (a) increased challenges to science as neutral, (b) continued assumptions of meritocracy in higher education, and (c) assimilation as representation. We also highlight exemplary articles that were most closely aligned with our conceptual framework, and then present three recommendations for future research efforts. A key goal of the present article is to call on researchers to more deeply consider the role of social identities in studies of geoscience education.

ARTICLE HISTORY
Received 08 September 2018
Revised 12 February 2019
and 07 August 2019
Accepted 13 August 2019
Published online
30 September 2019

KEYWORDS
Intersectionality; higher education; inclusive pedagogy; gender; race

Introduction

Concern about the underrepresentation of white women and people of color of all genders in the geosciences is increasingly reflected in the activities of field-specific professional societies, institutions of higher education, and disciplinary research journals such as the *Journal of Geoscience Education* (*JGE*). Research in this area has focused on overcoming barriers to the recruitment of minoritized communities in the geosciences and other scientific disciplines, and more recent attention has examined how retention is influenced by discrimination, bullying, and harassment in hostile learning and workplace climates. In their 2016 piece in this journal, St. John, Riggs and Mogk proposed that attention to professional ethics and interpersonal behaviors is key to building a strong and supportive community of practice in the geosciences. In light of recent reports that have documented widespread harassment and discrimination based on identity (see Clancy, Lee, Rodgers, & Richey, 2017; Gay-Antaki & Liverman, 2018) and the negative impact of these experiences on the recruitment and retention of members of underrepresented groups in the geosciences (Clancy, Nelson, Rutherford, & Hinde, 2014; Clancy et al., 2017), educational research that considers the role of social identities and how these affect individual and collective experiences can play an important part in promoting diversity and inclusion in the field.

Conceptual framework

Intersectionally inclusive geoscience environments

This synthesis of extant literature in geoscience education research (GER) was guided by a framework that draws from the social theory concept of intersectionality (Collins, 2015; Crenshaw, 1991) and interventions that can build learning environments that provide physical and psychological safety for diverse students, educators, and field professionals in order to prevent

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Table 1. Conceptual framework: Intersectionally inclusive geoscience environments.

Characteristics of research design that attends to intersectionality[1]	Characteristics of STEM spaces that are inclusive and free of harassment[2]
Recognizes that power is unequally distributed • Hierarchies in learning environments are identified (e.g., professors/ supervisors have more power and autonomy than students, and graduate students have more power than undergraduates). • History of institutionalized racism and sexism identified as roots of problem of "underrepresented minorities" (rather than focus on individual traits). **Acknowledges multiple and overlapping identities that create particular experiences of oppression** (e.g., students are not only categorized by gender or race, but both; other aspects of identity not always visible, such as socioeconomic status and disability, are addressed). **Recognizes that certain social locations provide more access to resources and power than others along different axes of identity in broader U.S. society** (i.e., in general, people identified as white or perceived to be white have greater access to certain opportunities than people of color; men and masculinity are afforded greater social status than women and femininity; those born in the U.S. or holding U.S. citizenship are less vulnerable than immigrants; speaking English as a first language speakers of other languages).	**Attempts are made to balance gender ratios and address dominance of men and masculinity in STEM spaces. Organizational climate that communicates intolerance of harassment.** • Interventions and supportive resources indicate a move beyond legal compliance to address culture and climate. **Higher education-specific interventions and commitments.** • Efforts are made to that diffuse hierarchical and dependent relationships (e.g., between trainees and supervisors). • Support is provided for targets of harassment and prevention efforts are implemented (e.g., bystander intervention training). • Transparency and accountability are assured in reporting and response mechanisms. • Leadership reflects and values diversity (e.g., adoption of affirmative action hiring policies).

Notes. [1]Intersectionality is a theory usually attributed to black feminist scholars Kimberlé Crenshaw (1991) and Patricia Hill Collins (2015) and informed by the work of critical race scholars. [2]We drew this list from the 2018 National Academies of Science, Engineering, and Medicine report authored by Johnson, Widnall, and Benya, but apply it to include the representation of people from additional minoritized groups (including but not limited to gender) and to counter harassment of all forms (including but not limited to sexual harassment). We focused on elements of suggested practice that could be considered in geoscience education research based in higher education settings.

harassment and discrimination. The application of this framework is in keeping with Lewis and Baker's (2010) call for the additional use of sociocultural theories in GER in order to promote positive change for teaching, learning, and research. First developed to explain how the identities of women of color are situated in particular structural and representational locations of overlapping oppression, the concept of intersectionality highlights how multiple socioculturally constructed identities exist simultaneously and create particular experiences of marginalization. Rooted in critical theory, intersectionality highlights how privilege and oppression are not equally distributed, and centers the distinct needs and experiences of individuals who belong to more than one marginalized group.

The second part of our framework is drawn from a report released by the National Academies of Sciences, Engineering, and Medicine (Johnson, Widnall, & Benya, 2018) that highlighted how sexual harassment is an institutional problem related to broader issues of discrimination based on gender and other identities. Recent research has revealed the prevalence of sexual harassment and assault experienced by trainees in disciplines that involve field training (Clancy et al., 2014) and how sexual and racial harassment disproportionately affect women of color's access to research and educational opportunities in the planetary sciences (Clancy et al., 2017). These reports, along with incidents reported widely in the scientific press, lead us to propose that the prevention of harassment is related to building anti-oppressive environments for study and learning in the geosciences. In Table 1 we[1] outline characteristics of research and educational interventions that would indicate alignment with this conceptual framework and draw readers' attention to the connections between understanding and acknowledging individual identities, identifying and rectifying power imbalances, and developing positive organizational cultures that support educational equity.

Methods

Defining the scope of the literature review

Research on higher education teaching and learning in the geosciences is an important site of analysis to examine how practices are developed and disseminated across classroom and research environments. Similar to Callahan et al. (2017), our review focused mainly on questions of *how* knowledge in GER has been accumulating, specifically applying a conceptual framework that elucidated ways that social identities were or were not considered in research on teaching and learning. We focused on work released since the *JGE* December 2007 "Broadening Participation" issue, collecting articles published between 2008 and 2018.

[1]The authors of this review are members of the ADVANCEGeo research team, an NSF-funded project focused on confronting sexual harassment and gender-based discrimination in the geosciences through the development and distribution of curricular materials. We believe that these problems cannot be addressed without a broader focus on representation and inclusion in the field, and that we should build on successful models already in place.

Table 2. Sample entry from analytic review matrix.[1]

Author(s), year of publication, article title	Palmer et al. (2009) Xoa:dau to Maunkaui: Integrating Indigenous Knowledge into an Undergraduate Earth Systems Science Course.
Setting	"Earth Systems on the Southern Great Plains," a multidisciplinary course offered at University of Oklahoma.
Participants/focus of intervention	Undergrad students enrolled in class (7/30 with Native American identities); Identities and roles of the faculty are clarified in addition to students in class.
Methods/study design	Formative evaluation of class, along with analysis of student evaluations at end of course ($n = 27$)
Outcomes/findings	Students wanted even more focus on indigenous knowledge; Native American students still unsure of geosciences as career path.
Significance	Includes use of storytelling and metaphors as teaching tools in geosciences; demonstrates connections between art and Earth surface features.
Alignment w/conceptual framework[2]	Lit review includes greater contextualizing (not just stats about Native American students, but coverage of different perspectives in curricular materials)—inclusion of historical context; explicit breaking down of hierarchical roles by involving students as teachers of younger students and other efforts to create cross-generational community.
SOE level[3]	**2** (case study of 1 class).

Note. [1]A total of 165 articles were included in the overall review. For ease of reading, the orientation of columns and rows has been reversed for this sample entry. The matrix used for the overall review includes one article per row, with column headings of Setting, Participants, and so on. [2]See Table 1 for overview of conceptual framework. [3]Strength of Evidence index from St. John and McNeal (2017): 1 = practitioner wisdom/expert opinion; 2 = qualitative and quantitative case studies; 3 = qualitative and quantitative cohort studies; 4 = meta-analyses; and 5 = systematic reviews.

Table 3. Overview of sources reviewed and relevance based on conceptual framework.

	Total number of articles selected for examination[1]			
Journal	Highly relevant	Somewhat relevant	Not aligned with conceptual framework	Total Number of Articles
Journal of Geoscience Education[2]	26	49	22	97
International Journal of Science Teaching[2]	2	7	12	21
Journal of Women and Minorities in Science and Engineering[3,4]	2	17	1	20
Journal of College Science Teaching[2]	1	6	7	14
EoS[3]	0	4	2	6
International Journal of Science and Mathematics Education[2]	2	0	3	5
Geosphere[3]	0	1	0	1
PLoS One[3]	0	1	0	1

Note. [1]We examined articles published in these journals between 2008 and 2018, in keeping with the goal of reviewing progress in *GER* since the publication of the December 2007 "Broadening Participation" issue of *JGE*. [2]Articles from this journal were selected and reviewed by the first author. [3]Articles from this journal were selected and reviewed by the second author. [4]Articles from this journal were selected and reviewed by the third author.

Search and selection

We began our review by identifying eight journals in which GER routinely appears, including but not limited to *JGE*. We then read the online table of contents for each issue of these journals published since 2008 and reviewed the abstracts for all articles with titles that were possibly relevant to the review. After filtering out articles focused on research conducted in K–12 educational settings and studies that did not involve collection of data from human subjects, we downloaded all remaining articles. This yielded a total of 165 selected articles, which we read in their entirety. We developed a matrix to summarize, compare, and contrast articles and to record details related to the conceptual framework and that categorized each article according to the Strength of Evidence pyramid proposed by St. John and McNeal in a 2017 issue of *JGE* (see Table 2 for a sample entry, with formatting adjusted for publication). We coded each article based on its alignment with our conceptual framework's focus on building intersectional and gender-inclusive geoscience spaces in higher education, and the ways and degree to which student, faculty, or researcher identities were considered in the research. Table 3 presents an overview of the total number of articles categorized as "highly relevant," "somewhat relevant," or "not aligned with conceptual framework."

For example, the study presented in the article summarized in Table 2 was rated as "highly relevant" based on both methods and content: Native American identities were explicitly discussed, indigenous knowledge was valued and centered, higher educational power dynamics were shifted (undergraduates were engaged in outreach to younger students, faculty were described primarily as mentors rather than content experts), and developing respectful community relationships was emphasized. By attending to faculty and researcher identities, identifying existing hierarchies that have marginalized Native identities in the geosciences and in higher education, and deliberately valuing the input of communities that have been systematically excluded from institutional leadership,

this type of research both identifies the conditions under which discrimination based on identity can occur and suggests ways to prevent it.

We employed an iterative analysis process that began with preliminary review and coding of articles in specific journals by individual authors (see Table 3). Following clarification and comparison of matrix entries among the three authors, the first author identified positive exemplars aligned with the conceptual framework and preliminary themes based on patterns across the data set. The final results were reviewed and clarified through discussion with the third author.

Results of analysis and discussion

In this section we present and illustrate three primary themes identified through our analysis: (a) increased challenges to science as neutral, (b) continued assumptions of meritocracy in higher education; and (c) assimilation as representation. After a summary of the significance of our overall findings, we present exemplars of GER that promotes inclusivity through an intersectional focus on identity.

Increased challenges to assumptions of science as neutral

Most physical and natural scientists—and many geoscience education researchers—were trained in experimental methods and inquiry approaches that aim to control for variability when examining a phenomenon. This has often led to an assumption that science itself is therefore objective and neutral, despite the numerous ways that scientists' personal perspectives guide their research. We found that a growing number of GER articles published since 2008 have begun to take alternative stances; many articles have discussed the nuanced ways that science is a process and a human endeavor—one that is potentially subject to bias and can influence public decision making (Apple, Lemus, & Semken, 2014; Bond, Philo, & Shipton, 2011; Feig, 2010; Kluver, Robertson, & Agardy, 2018; McNeal, Hammerman, Christiansen, & Carroll, 2014; Nadelson & Viskupic, 2010; Pelch & McConnell, 2017; Ward, Semken, & Libarkin, 2014).

In an evaluation of how college students developed understandings of human impacts on climate change, Nam and Ito (2011) focused on the importance of information literacy and discussion of different perspectives in groups, along with the application of scientific reasoning to arrive at a conclusion. Laursen and Brickley (2011) noted that college students were frequently surprised by the amount of collaborative work in which they saw scientists engaging, and listed observations students made about the people who do science, including gender, race, nationality, and dress or appearance. To more comprehensively and accurately study student interest in particular science fields, researchers should take care to identify distinctions between content-specific knowledge, perceptions of science domains overall, individual understandings, and collective activities (Krapp & Prenzel, 2011).

Reichert, Cervato, Larsen, and Niederhauser (2014) noted the social implications of science by drawing connections between support for climate change policy and public understanding, and the importance of considering personal values in developing critical thinking skills was highlighted by Yacobucci (2013, p. 351), "because many aspects of geoscience research have social and ethical implications."

Several articles presented science itself as an act of advocacy (e.g., Palmer, Elmore, Watson, Kloesel, & Palmer, 2009; Unsworth, Riggs, & Chavez, 2012). Koretsky, Petcovic, and Rowbotham (2012) promoted a community-oriented, service-learning approach to geoscience education that emphasized effective communication with peers and the public as essential parts of preparation for careers in the field. Canetto, Trott, Thomas, and Wynstra (2012) and Murray, Napieralski, Luera, Thomas-Brown, and Reynolds-Keefer (2012) suggested that efforts to diversify the geosciences should emphasize ways that careers in the field can have positive social impacts and solve community-based environmental problems.

Acknowledging the dominance of Western models of logical empiricism in science, technology, engineering, and math (STEM) fields, and how these differ epistemologically from more holistic and contextualized bases of knowledge that guide indigenous science perspectives, is important in expanding culturally relevant practices that can increase the participation of people from underrepresented backgrounds in STEM and invite new research perspectives and practices (Abrams, Taylor, & Guo, 2013), and understanding science as a process that can change over time can be part of enhancing students' opportunities to see themselves as scientists (Kinner & Lord, 2018).

Continued belief in meritocracy of higher education

A clear commitment to expanding student participation and representation is demonstrated in the GER literature, yet most studies continue to reflect narrow

understandings of what constitutes academic success. We found widespread evidence of instructor beliefs that academic success is primarily attributable to the amount of effort expended by students or natural aptitude, rather than more nuanced considerations of systemic issues of marginalization and barriers to access. Articles on instructional strategies were typically framed by literature reviews that did not address student identity but, rather, reported typical performance of students enrolled in similar classes based on narrow parameters. The way most evaluation or empirical studies in GER are presented also reflects a belief that instructors can achieve a degree of objectivity in their practice, or that standardized instruments can be used to objectively measure student achievement. Markley, Miller, Kneeshaw, and Herbert (2009) even found that most faculty included in their study did not perceive teaching practices as highly influential on student learning outcomes.

When responsibility for success is placed almost entirely on students, failure is therefore often attributed to lack of internal motivation or intellectual capacity. As demonstrated by Bejerano and Bartosh (2015), however, gendered norms and expectations influence the development of scientific identities, including the sense of oneself as a capable student. Studies that address gender differences without making note of broader social contexts of inequality—especially in fields with inconsistent gender representation, like the geosciences—may overlook important explanatory data for student success. In their analysis of factors that predict student performance on field assessments, Dykas and Valentino (2016) suggested that women may feel more stressed because they are less academically prepared, but they did not consider that stress in fieldwork might be caused by specific gendered vulnerabilities, including to sexual harassment (see Clancy et al., 2014). In their examination of decision-making processes relative to their careers in the geosciences, Canetto et al. (2012) found that women frequently incorporated concerns unrelated to confidence in their abilities as geoscientists or interest in pursuing future opportunities—for example, heterosexual-identified women took their male partners' goals into account when making career decisions, although none of the heterosexual-identified men reported considering their female partners' goals. Sallee and Pascale (2012) suggested ways that institutions should specifically address the multiple burdens faced by women scientists with children because of differential career impacts for men and women with families.

Assumptions of natural talent or academic commitment as primary indicators of achievement can obscure the importance of structures that systematically restrict opportunity for certain groups, starting early in students' educational careers. Here again, identity matters, because those who have been successful in traditional modes of STEM instruction are the minority rather than the majority of students. Even faculty who attempt to change their instructional strategies may reproduce these same inequitable relationships if they do not deliberately challenge these underlying beliefs about meritocracy.

These unchecked assumptions are especially evident in studies that involve the assessment of spatial reasoning or visualization skills, given that historically men have been perceived to be naturally better than women at these skills. For example, Feig (2010), suggested that *most* students struggled with applying spatial skills to field work, and that demonstrations beyond classrooms would be valuable for researchers interested in spatial skills development to consider when examining the implications of performance on classroom assessments. Shields (2018) and Gold et al. (2018) also argued that gender differences in spatial reasoning are due to socialization and not to innate differences in ability, and Ormand et al. (2014) found that performance on spatial reasoning measures had little impact on academic performance. Colaianne and Powell (2011) found that students taking courses across liberal arts disciplines could enhance their spatial abilities and apply these to geology coursework. Given this context, GER could support efforts to reduce gender discrimination in the geosciences by reframing the way that spatial skills are considered. Most studies, however, continue to reinforce gender-based differences in skill level, despite research to the contrary.

A growing body of work outside the geosciences specifically supports the notion that using traditional achievement measures to track student success ignores histories of limited access to higher education. Work that has incorporated additional perspectives includes Ceglie's (2011) study of how women of color develop science identities and Cole and Espinoza's (2009) exploration of how gender identity impacted how STEM students of color experienced their campus climates and resulting impacts on academic outcomes. Williams and George-Jackson (2014) also documented continued differences in perceptions of STEM self-efficacy based on gender identity.

One example of a recruitment and development model that directly counters a focus on traditional

measures of performance was documented in an article by Stassun, Burger, and Lange (2010) that described a bridge to the Ph.D. program that specifically avoided looking for the standouts and instead sought "diamonds in the rough"—focusing on promise rather than elitism, and creating partnerships between research universities and local minority-serving institutions. Similarly, Fortenberry et al. (2009) documented the need for more institutional connections to improve the representation of students of color in STEM fields.

Cervato and Flory (2015) found that instilling a sense of belonging as well as building content knowledge was important in a successful high school to college transition program. Espinosa (2008) reported specific experiences that helped support academic self-concept in Latinx and African American men and women STEM students. And Hammersley, Levine, Cornwell, Kusnick, and Hausback (2012) found that Hispanic students participating in a course that aimed to be more culturally relevant ("Geology of Mexico") earned grades comparable to those of their white peers, countering a trend in other geology classes.

Assimilation as representation

Committed advocates in the geosciences have worked for decades to diversify labs, classrooms, and workplaces and have achieved some measurable degrees of success. Overall measures of diversity in the field, however, suggest limited overall progress (Bernard & Cooperdock, 2018). The proportion of women faculty in many geoscience fields has increased over the last decade (Wilson, 2017), although percentages remain lower than the overall STEM workforce (Wilson, 2019). These changes appear to reflect increased representation of white women, as the number of students of color in the geosciences have shown no improvement in 40 years (Bernard & Cooperdock, 2018). Employing an intersectional perspective provides a lens not to critique these previous efforts as failed but to suggest that a more structural analysis is needed in order to more effectively promote greater participation in the field. Many efforts to increase the representation of women and minoritized racial and ethnic groups in the geosciences have focused on developing individual skills and capacities to increase success within existing structures. Although well-meaning, such initiatives frequently overlook how existing norms and expectations in the geosciences are modeled in higher education settings and do not address how these norms exclude many people. Rather than changing the culture of institutions, many efforts attempt to change individuals so they can participate in these spaces as they currently exist. The title of an article exploring the experiences and perceptions of tenured women STEM faculty by Tyson and Borman (2010) serves as an apt example: "We've all learned a lot of ways not to solve the problem."

Initiatives that aim to assimilate individuals rather than change institutions are often guided by implicit assumptions about students from certain backgrounds that are frequently inaccurate; one article, for example, assumed that people of color are located exclusively in urban areas and did not have access to "dynamic scenery." More positive examples that focus on broader cultural and structural influences and attend to differences based on individual identity do exist in the literature, however.

For example, Mack, Johnson, Woodson, Henkin, and Dee (2010) examined how organizational trust and institutional supports had positive or negative impacts on faculty sense of empowerment and compared differences across career stage and gender. In a 2012 article, Unsworth et al. examined the impact of a program designed to support the entry of Native American students into the geosciences. They found that after completing the program, participants still conceptualized the categories of "scientist" and "Native American" as distinct in broader social contexts but were more likely to feel proud of their cultural heritage and see science as a viable career option that did not conflict with this identity. Parham et al. (2010) also identified how self-reinforcing conditions contribute to the overrepresentation of white men in the geosciences—underlying assumptions that students with these characteristics are naturally better at science can lead faculty to provide more encouragement, which therefore leads to a greater likelihood they will stay in the field. Focusing on individuals rather than structures as the point of intervention can limit the long-term or broader effectiveness of programs designed to invite more people to the field.

Research that takes a more nuanced look at the persistent underrepresentation of white women and people of color in the geosciences demonstrates the need for additional perspectives and greater attention to context. Although some programs have focused on broadening students' ideas of who can participate in certain fields by introducing them to professionals from diverse backgrounds (see Hallar et al., 2010, for a description of such efforts in the atmospheric sciences), many studies have focused on pipeline issues overemphasizing counting numbers of people from

certain groups rather than encouraging cultural change. This approach can also reinforce other mistaken interpretations, such as the model minority myth; Hanson and Fang (2009) demonstrated that although Asian scientists are well-represented in terms of numerical presence in many STEM fields, racialized stereotypes and negative work climates contribute to lower reports of satisfaction than white peers. This is not to say that representation does not matter—Mattox et al. (2008) found that physical geology textbook photos of people doing science did not match the overall population, and a 2014 study by Sexton, O'Connell, Banning, and Most documented the way that faculty photographs on department websites reinforced images of geoscientists as mostly white, male, and in careers that spend a great deal of time outdoors. A recent study from the medical profession revealed how historical portraiture in medical school halls can signal exclusion (Fitsousa, Anderson, & Reisman, 2019).

The role of mentoring and role models is an area of research in which representation is particularly salient. Interpersonal relationships can be highly influential on whether individuals remain in the field. Studies have shown the importance of faculty assistance in helping students transfer from two- to four-year institutions (Wolfe, 2018) and in encouraging or discouraging them from science coursework (Sherman-Morris & McNeal, 2016). Access to field experiences and mentoring can impact geoscience student success (Rathburn & Putman, 2018), and ongoing mentorship can enhance career satisfaction and retention of Earth sciences majors (Cervato & Flory, 2015; McCallum, Libarkin, Callahan, & Atchison, 2018).

Hernandez et al. (2017) found that women mentors supported persistence of female students, but Baber, Pifer, Colbeck, and Furman (2010) discussed the importance of building relationships across identities to avoid tokenizing students or faculty, and instead placing greater responsibility on faculty from majority groups to learn how to be better mentors to students from different backgrounds.

Student expectations and faculty mentoring styles also should be taken into account when pairing trainees with mentors (Houser, Lemmons, & Cahill, 2013). Schupp, Irwin, Marasco, and Asher (2018) described how new mentoring programs look to take advantage of technology to link students with mentors at other institutions, which could also enhance perceptions of diversity in the field. Other efforts aim to highlight the diversity of gender and ethnicity of current geoscientists, such as Project GAP, described by Adetunji et al. (2012).

In order to be effectively prepared for the contexts they are likely to encounter as geoscience students or professionals, however, white women and people of color should also be informed that they will likely need to navigate sexism and racism in the field. Because of differences in social positioning, some mentoring relationships may be materially more "useful" than others (Callahan, Libarkin, McCallum, & Atchison, 2015). As Callahan et al. (2017, p. 573) stated:

> We might conceive of the diversity of our community as an indication of its relative health. There is no question that past efforts have been important in bringing us to our current understanding. The treatments, however, have been largely prescriptive. The persistent underrepresentation of minorities in geoscience, and STEM more broadly, indicates that our prospects are not nearly as robust as they could be.

Instead of focusing on how to assimilate promising students into an existing culture of geoscience, the geosciences themselves must adapt to be more inclusive. Such an approach involves a focus on changing shared social practices rather than changing individuals.

Conclusions

A key finding of our review is the *absence* of a focus on identity in a majority of GER published over the last 10 years. As we examined the literature, a primary reason for coding articles as not aligned with our conceptual framework of intersectionally inclusive learning environments was the limited manner in which students and instructors were considered in the research presented: In general, connections to a geoscience classroom were the only details included. Instructors were typically identified by years of teaching experience and the age or level of students taught, whereas students were typically described in terms of major or subject area, year in college, the size of the course in which they were enrolled, and whether they were working individually or cooperatively. Many studies of instructional interventions or evaluations of activities or programs exclusively addressed content preparation and familiarity with concepts, without measuring other outcomes that are known to be associated with retention, such as aspects of social well-being.

Some articles went as far as to indicate specifically that factors such as gender and ethnicity were not of

interest and were therefore not included in data collection. We find this to be an especially notable oversight in articles that focus on field camp and other beyond-the-classroom activities, because of the documented disparate impacts on women in these spaces (Clancy et al., 2014). Other studies included these data in tables that contextualized or introduced the study but did not address their potential impact in any other way in the study. In several studies, data tables summarizing participant characteristics indicated strong gender imbalances, but the authors did not discuss these numbers other than referring to them as reflective of the major or field as a whole and not in terms of contextualizing the study findings. Similarly, ethics and professional values were rarely mentioned. When present, they were more likely to be referenced in terms of discussing climate change, scientific integrity, and environmental responsibility rather than in terms of educational relationships.

In accordance with our conceptual framework based on social critical theory, we suggest that considering power dynamics will enhance the ability of geoscience education research to promote equity and inclusion efforts in the field. Although likely a reflection of the attempt of researchers to establish a degree of objectivity in their work, we suggest that including such elements would in fact strengthen the ability of such work to have impacts beyond the specific setting in which they were collected and can more adequately address the complex nature of teaching and learning in higher education. This approach is also in keeping with the recent stance taken by some major scientific societies, including the American Geophysical Union (AGU), and funding agencies such as the National Science Foundation (NSF) to define harassment as a form of scientific misconduct (AGU 2017; Marín-Spiotta, 2018; NSF 2018).

Our review also revealed that, although the use of qualitative research methods is growing in GER and several excellent examples exist (see, e.g., Feig, 2010; Stokes, Levine, & Flessa, 2015), the extant literature reflects a relative lack of familiarity with the full potential uses of related methodologies. For example, at least two studies suggested that qualitative modes of analysis were employed because of a lack of sufficient data to employ statistical analyses, and another noted that the qualitative data the researchers had collected "required little analysis." These statements likely reflect a misinterpretation of the selection of qualitative research approaches rather than a belief that quantitative methods are better or more appropriate. Because qualitative research methods allow for greater nuance and inclusion of the impact of social identities on teaching and learning, additional work of this type can yield important explanatory interpretations.

Even among studies that employed qualitative methodologies or methods, the acknowledgment of researcher positionality that is fundamental to most research using these approaches was missing in many publications and reinforced the absence of a focus on identity. (Notable exceptions include the identification of the indigenous heritage of one of the faculty researchers in Palmer et al., 2009, and the description of the gender and racial identities of the raters involved in analysis in Stokes et al., 2015.) More detailed descriptions of participants in qualitative studies enhance their potential for generalizability and clarify how trustworthiness (a corollary of validity and reliability assurances) is considered in research design. In one useful example, McNeal et al. (2014) provided contextualizing details such as students' religious and political affiliations when considering the analysis of qualitative data collected in their study on student engagement, knowledge, and perceptions of climate change. Given the social context in which people come to understand science, these details are important for readers to identify how one study's findings can inform their own practice. Including additional details can also help researchers avoid unintentionally reinforcing deficit assumptions about students from underrepresented backgrounds and provide more detail about how identities can overlap and influence one another.

Exemplars of intersectionally inclusive geosciences education research

We identified six articles (presented here in chronological order) published since 2008 in *JGE* that were most closely aligned with the conceptual framework that guided our inquiry and provide evidence of promising practices. As the key journal publishing work in the emerging field of geosciences education research, *JGE* can make an important contribution to the broader geosciences community and other areas of STEM education research. In these studies, researchers not only focused on the identities of those involved in the studies but also examined differences in their experiences based on these identities. In keeping with an intersectional perspective, they acknowledged how power is unequally distributed among participants, communities, and in the geosciences. This awareness is a necessary precursor for the prevention of

harassment because it reveals how some individuals are situated in more vulnerable positions.

Unsworth et al. (2012) introduced an article that described a bridge program designed to introduce Native American youth to the geosciences by emphasizing the influence of social context, noting, "federal government and history is replete with examples of resource dispossession over Native objections" (p. 384). The authors recognized existing knowledge and assets of Native American communities and drew connections to the objectives of community-oriented geoscience. Participants were invited to provide self-descriptions that allowed for greater nuance, and within-group as well as between-group differences were referenced.

In describing the Atmospheric Science Program at Howard University, Morris, Joseph, Smith, and Yu (2012) discussed how navigation of different levels of institutional hierarchy was necessary to establish and fund the initiative. Student data were disaggregated by race and gender, both faculty and student issues were reported, and the role of minority-serving institutions in addressing historical discrimination in higher education—especially of African American students—was also discussed.

Ward et al. (2014) described a study that developed place-based geoscience assessments for the Blackfeet and Diné (Navajo) communities that focused on changing a practice of measuring conceptual understanding rather than merely adjusting existing assessments. Their work also addressed hierarchies by shifting assumptions of expertise to local community members rather than geoscientists.

Similarly, Dalbotten et al. (2014) described a cross-generational program that connected K–12 students with community elders, college students, and faculty from different institutions to implement a program focused on holistic approaches to learning. They applied a conceptual framework that emphasized trust- and relationship-building between researchers, teachers, students, and Native American community members, and developed STEM pedagogical strategies that were culturally situated.

Stokes et al. (2015) also consulted existing literature in developing a sociocultural approach to understand students' decision making around choosing a geoscience major, discussed research on implicit biases, and found specific ways that Hispanic students and women experienced their majors differently than white students and men. Based on their review of others' work, the authors summarized "a traditional geology curriculum loses its effectiveness if learners are forced to create new meanings for preexisting cultural constructs" (Stokes et al., 2015, p. 251).

Hendricks, Atchison, and Feig (2017) also demonstrated how structural barriers can result in complicated negotiations of self-advocacy for geoscience students and faculty with disabilities participating in field experiences. Their study included first-person narratives that documented the perspectives of individuals with physical, sensory, or cognitive disabilities and illustrated how marginalization based on identities outside the norm of a social group can reduce learning; they concluded by calling for geoscientists to provide opportunities for all learners to build on their strengths.

Recommendations

Based on our review of the last 10 years' of geosciences education research, we offer three suggestions for future work that could help promote diversity and inclusion efforts in the geosciences. Based on our conceptual framework, we suggest that conducting educational research that includes attention to social dynamics in learning environments will create new opportunities to make these spaces safer and more welcoming for geoscientists from all backgrounds.

Increased focus on the role of individual and collective social identities

First and most important, geoscience education researchers should attend to student and instructor identities and expand understandings of identity in study design and data collection. Investigations that explore group dynamics in educational settings should especially attend to multiple identities, intersectionality, and within-group differences. Researchers should be careful to avoid conflating chromosomal/biological sex with gender and be clear about how they categorize participants. When possible, students should be invited to self-identify, and categories beyond binary assumptions of men and women should be included. Stokes et al. (2015), for example, included cisgender as one option among others, and Stofer (2016, p. 234) described participants as "presenting male by name and appearance."

When collecting data about student race and/or ethnicity, researchers should avoid reinforcing assumptions of whiteness as standard, and avoid using overly generalized categorizations. Several articles we reviewed, for example, reported students in ways such as "percentage Caucasian," "white or nonwhite," or "Asian/Caucasian/underrepresented." Labels such as

these are less than accurate at best and dehumanizing at worst.[2]

Additionally, disability status and socioeconomic class are important factors to include in studies that seek to explain differences in academic experiences. A study by Hendricks et al. (2017) was one of the only articles we found that focused on accessibility as a goal. We echo Carabajal, Marshall and Atchison's (2017) call for additional consideration of accessibility and disability status in GER. We also suggest that more ethnographic research studies would complement existing research in the field and help illuminate the experiences of members of minoritized groups in the geosciences.

Expanded use of qualitative data and epistemologies

Second, we promote the expanded and deeper use of qualitative methodologies and critical epistemologies. We encourage geoscience education researchers with traditional training in physical and quantitative sciences not to equate descriptive coding of qualitative data with analysis but, rather, to think of it as one step in a more extended interpretive process. Qualitative data present the potential for deeper interpretation and have more explanatory potential with additional analysis, as presented in studies such as that by Lukes and McConnell (2014), which included a useful flow chart of their qualitative analysis process, and Canetto et al. (2012), in which researchers conducted a qualitative interview study that sought to explore gender differences in graduate students in the atmospheric sciences. Sexton (2012) similarly provided a more detailed explanation of analytic process and clarified the steps taken to establish trustworthiness in an investigation of students' conceptions of the roles of rivers in canyon formation.

Two strong examples of mixed methods research that demonstrated awareness of how multiple student characteristics can impact their experiences are Baber et al. (2010), in which researchers developed an interview protocol designed to prompt students to discuss significant events or interpersonal interactions that were linked to their interest in the geosciences, and a discussion in Murray et al. (2012) about how addressing power dynamics is essential to the appropriate application of focus group methods. Arthurs, Hsia, and Schweinle (2015) also clearly described the theoretical assumptions related to their mixed methods assessment of the development of a concept inventory to assess student knowledge of oceanography using grounded theory analytic approaches for the qualitative component and item response theory for quantitative analysis.

Some researchers also did more to clarify the ontological assumptions about students, teachers, and learning that guided their research. Dohaney, Brogt, and Kennedy (2015), for example, described starting assumptions involved in their use of cognitive load theory to frame research on students' note-taking skills. Given the increased use of mixed methods in educational research, more attention is needed in this area to ensure that researchers are accurately addressing the epistemological differences between qualitative and quantitative approaches to inquiry and demonstrating an awareness of the blending that occurs in such studies.

Increased support for collaborative longitudinal research

Finally, we echo the call of others for more longitudinal research studies about the impact of programs and courses designed to recruit students from underrepresented backgrounds to the geosciences (e.g., Baber et al., 2010; Levine, González, Cole, Furhman, & Le Floch, 2007; Lewis & Baker, 2010). These studies need to focus on more than academic achievement; studies should also focus on whether students are retained as majors in geoscience departments, and whether they continue in the field in professional roles. Much research in GER touches on elements of these questions, and we encourage members of the research community to build on the work that has been done. Promising examples include a study that followed a group of young women who participated in a middle-school STEM enrichment program to college to track the impact of early exposure to such opportunities (Hughes, 2015) and a report in which White, Reddy, Liu, Williams, and Shoemake (2013) described "30 years of meteorological education at an HBCU," including statistics about program graduates and their professional roles.

Future research in these areas can build on past strengths and address existing challenges to increasing diversity and inclusion in the field of geosciences education research.

Funding

This work was supported by U.S. National Science Foundation ADVANCE Partnership Award #1725879.

[2]We would particularly like to draw researchers' attention to the racist history of the term "Caucasian." A useful explanatory reference is Mukhopadhyay (2008).

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