Theoretical Perspectives on Increasing Recruitment and Retention of Underrepresented Students in the Geosciences

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ABSTRACT

For decades, programs targeting the recruitment and retention of underrepresented minorities (URM) have had local success in broadening participation in the geosciences. Meanwhile, national graduation rates of URM geoscience majors fall below the national graduation rates of URM STEM majors, generally. In this literature review, we summarize methods used to investigate the efficacy of geoscience recruitment and retention programs, and we propose avenues of future investigation into why programs are successful. First, we categorize a decade of recent publications in the *Journal of Geoscience Education* (JGE) according to Astin's Input–Environment–Output (IEO) model. This model offers a classification scheme to evaluate how inputs (e.g., student characteristics) and environment (e.g., program attributes) may influence desired outputs (e.g., results of programs). Next, we discuss a set of social, cognitive, and psychological theories that support deeper investigation into the reasons why recruitment and retention programs are successful with particular groups. There is an observable trend in the geoscience literature after 2009 toward interventions that include all components of the IEO model and random assignment (i.e., "natural experiments"). We argue that self-efficacy, identity, microaggressions, stereotype threat, and social cognitive career theory offer perspectives that can guide future programmatic interventions and support the geoscience community in broadening participation in the geosciences. [DOI: 10.5408/16-238.1]

Key words: diversity, broadening participation, theoretical frameworks

INTRODUCTION

The persistent underrepresentation of racial and ethnic minorities (URM) in the geosciences is widely known and well documented (Huntoon and Lane, 2007; Riggs and Alexander, 2007; National Academy of Sciences [NAS], 2011; O'Connell and Holmes, 2011; National Research Council [NRC], 2013; National Science Foundation [NSF], 2015). Over the past several decades, there has been significant financial investment to address this underrepresentation and to broaden participation of URM in the discipline. For example, from 1972 to 2012, the American Geosciences Institute (AGI) administered the Minority Participation Program using funding from various sources to provide scholarships and mentoring relationships for URM undergraduate and graduate students in the geosciences (Callahan et al., 2001). Between 2002 and 2013, the NSF program, Opportunities for Enhancing Diversity in the Geosciences (OEDG), infused tens of millions of dollars into projects with the express purpose of increasing the number of individuals from underrepresented groups in geoscience degree programs and careers (Karsten, 2013). Admittedly, efforts over the past several decades have not yet had a significant community-wide impact on changing the demographics, as is evident in low numbers of URM in degree programs and professional fields (Wilson, 2014; NSF, 2015; Sidder, 2017). Locally, though, these projects have yielded some specific recommendations for recruitment and retention of URM in the geosciences (Huntoon and Lane, 2007; Riggs and Alexander, 2007; NRC, 2013). In their paper, "Macrosystem Analysis of Programs and Strategies to Increase Underrepresented Populations in the Geosciences," in this special issue of the *Journal of Geoscience Education*, Wolfe and Riggs reexamine the characteristics of such programs.

This fresh synthesis is valuable for identifying what strategies are successful; by contrast, our purpose here is to present a literature review that probes questions related to how and why those strategies may be successful. In traditional geoscience research, there are scholars who concentrate on studying a particular geographic region and those who concentrate on developing skills in a particular methodology and applying it to a host of problems. In science education research, literature reviews that focus on methodology are not common (e.g., Randolph et al., 2008; Ravitch and Raggan, 2012). Much of the literature on broadening participation in the geosciences has concentrated on understanding the problem of underrepresentation without raising questions about the methodology of how we have acquired that understanding. This literature review helps address that deficiency: we assess where we stand as a community with regard to *how* we have been accumulating knowledge about increasing diversity; we are not trying to assess *what* we know about increasing diversity.

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Our approach is two-fold. First, we review articles that describe programmatic efforts to increase diversity in the geosciences. Second, we discuss a selection of theoretical frameworks that may be useful in understanding how to design future intervention efforts. We begin by explaining the reasons for our particular approach and use this explanation to frame the objectives guiding this literature review.

FRAMING THE PROBLEM

By the conclusion of the long-running NSF program OEDG, geoscientists seeking suggestions for how to develop programs to recruit and retain URM to the geosciences had numerous publications from which to draw ideas (e.g., Huntoon and Lane, 2007; Levine et al., 2007; Riggs and Alexander, 2007; NRC, 2013). Notably, recommendations focused on actions to implement, opportunities to offer, or individual characteristics to foster increase interest with a summer program (e.g., Carrick et al., 2016), connect students with a mentor (e.g., Judge et al., 2012), and support students' perceptions of their ability to succeed (e.g., Baber et al., 2010). The question, though, is to what extent have instances of these interventions in the geosciences been explicitly informed by research into why these interventions are most important.

Consider, for example, a common strategy to recruit and retain URM to science, engaging undergraduate students in original research (e.g., NRC, 2013). Students and faculty alike credit the research experience as helping URM students develop their interest and commitment to science (e.g., Seymour et al., 2004; Judge et al., 2012). Why do these strategies work for some students and not others? Is timing—whether onset or duration—important and, if so, in what way? What is the hazard for the student if the experience goes awry? What if the relationship with the mentor is not satisfactory? Or what happens if the project encounters problems? Outside the geosciences, an expansive literature exists with answers to many of these questions (e.g., Bell et al., 2003; Hurtado et al., 2009; Roberts and Wassersug, 2009; Thiry and Laursen, 2011; National Academies of Sciences, Engineering, and Medicine, 2015). Moreover, research on recruitment and retention typically employs methodologies grounded in theoretical frameworks. In the social sciences, theoretical frameworks serve as a blueprint to guide the articulation of research questions, what data are collected, and how data are analyzed and interpreted (e.g., Shavelson and Towne, 2002; Ravitch and Raggan, 2012). Theoretical frameworks draw a researcher's attention to certain elements of an individual's experience or environment, since it would be arguably impossible to focus on all elements simultaneously.

For the first part of this review, we investigate what kinds of data have been collected and analyzed about student demographics and backgrounds, students' experiences in a given program, and measures of outcomes in diversity projects in the geosciences. To structure this review, we adopted A.W. Astin's Input–Environment–Output (IEO) model, as used for assessment in higher education (Astin and Antonio, 2012); this model will be defined more fully in the next section. Briefly, however, the IEO model enables an assessment of program success by not only considering data related to the students' lived experiences but also by including data related to the initial backgrounds of students. We present a review of papers describing programmatic efforts to increase diversity in the geosciences to address the following question: How often have we as a community collected and analyzed data about who was involved, what their experiences were, and what were the outcomes of the project?

The second part of this review is based upon our findings in the first. We present a selection of cognitive, social, and psychological theories. Please note that we use the terms ''theoretical framework'' and ''theory'' interchangeably as synonyms in this paper. For each theory, we provide a definition and a discussion of how it is applied. Thus, instead of merely recommending that future interventions or studies be situated in theories, our approach is to provide specific examples to demonstrate the utility of theoretical frameworks.

ASSESSMENT OF PAST PROGRAMS USING THE IEO MODEL

Defining the Scope of the Literature Review

We focused our review on studies that described the impact of programs or other interventions designed to increase the participation of URM in geoscience. This means we are setting aside work that did not describe specific programs or interventions, such as the study by Sherman-Morris and McNeal (2016). We also excluded past summaries articles (e.g., Huntoon and Lane, 2007; Riggs and Alexander, 2007; NRC, 2013; NSF, 2015).

We used the following series of terms to identify possibly relevant papers: *diversity*, *underrepresented*, *minorities*, *Latino/Latina*, *African American*, *recruitment*, and *retention*. The *Journal of Geoscience Education* (JGE) is the primary peer-reviewed venue for geoscience education research. Searches in other journals, such as the *International Journal of Science Education* and the *Journal of Women and Minorities in Sciences and Engineering,* did not yield significant contributions on the topic of recruitment and retention in the geosciences. Therefore, literature reviewed in the remainder of this section is limited to JGE.

Using our search parameters, we found 46 publications, dating from 2003 through 2016. In December 2007, JGE published a special issue entitled *Broadening Participation in the Earth Sciences*; the issue was co-edited by Eric Riggs and Claudia Alexander and included 19 papers. We found only one paper published in JGE prior to 2007 on recruitment and retention (Bingham et al., 2003) and chose to exclude it from this analysis so we could evaluate a period of continuous publication on the topic. The remaining 45 papers were included for review.

Defining Our Framework

We selected Astin's IEO model (Astin, 1984; Astin and Antonio, 2012; Renn and Reason, 2013) to organize our review of past studies (Table I). Astin and Antonio (2012) provide a review of how the IEO model can be used as a framework for analyzing interventions in higher education. *Input* in the IEO model refers to student characteristics such as demographic background, sociocultural experiences prior to college, and measures of college readiness. *Environment* refers to student experiences in academic or cocurricular settings as defined by a particular intervention—either a

TABLE I: Summary IEO framework presented in Astin and Antonio (2012).

Design	Example Data	Defined By	Limitations
I and O only	Pre- and post-test data without description of intervention	Description of the change over time of a particular variable	Assumes change in data is attributable to intervention without considering other possible environmental factors
E only	Review of course syllabi	Rich description of program without data on students or measures of outcomes	Assumes what is described is equal to what is gained by students
O only	SAT or ACT scores	Description of output data without any discussion of environment or input variables	Assumes input characteristics are equal across all students; assumes resources and experiences are equal across all environments
E and O only	Achievement data from K–12 students	Description of output and environmental variables	Assumes change for one student is comparable to change for another student; assumes input characteristics are equal across all students
IEO	Pre- and post-test data with description of intervention	Output measures related to environment and input variables	No control group data or random assignment
IEO Exp	Pre- and post-test data; description of control versus treatment groups	Output measures related to comparison between treatment and control settings	Assumes input characteristics are equal (i.e., no random assignment)

curricular experience (e.g., classroom teaching techniques) or cocurricular experience (e.g., mentored summer research). *Output* refers to the desired outcomes expected after a student participates in an intervention. The outcomes of an intervention are affected by inputs (e.g., students' characteristics) and environment (e.g., activities or actions involved in the intervention). Central to this model is that there is alignment between the three components of input, environment, and output (Fig. 1); the cyclical nature with respect to the association between inputs, environment, and outputs is also significant.

The IEO model bears some similarities to logic models, another method used for program evaluation in higher education (e.g., NRC, 2013). Both approaches measure how inputs and activities may influence desired outcomes (Wholey, 1983, 1987; McLaughlin and Jordan, 1999; Astin and Antonio, 2012). For both, the ideal condition for program evaluation occurs when the outcomes are considered in relation to the inputs and activities. As described by Astin and Antonio (2012), the IEO model has an advantage in that it addresses circumstances when that ideal condition is not met. For example, if a program was implemented based on best practices but was unsuccessful in increasing participation, the IEO model includes enough detail to evaluate why this may be the case. The following paragraphs summarize the possible configurations of the I, E, and O components in a program evaluation.

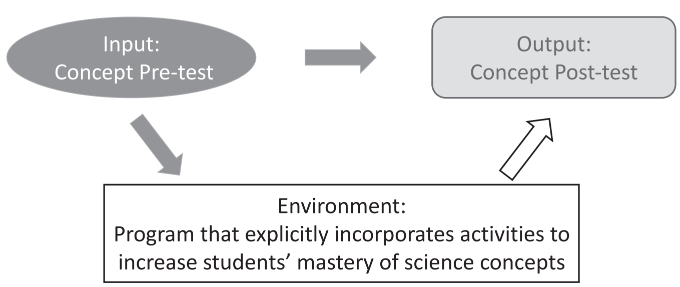

FIGURE 1: Example research design aligned with the input, environment, and output elements of Astin's IEO model. This model highlights how inputs and environmental factors interact to produce outcomes (i.e., outputs). In this example, the input variable is a specific data set. However, researchers may not always have control over input variables of interest. Instead, researchers are more likely to have control over constructing an inclusive and engaging environment that supports all learners.

It makes sense to begin by describing the circumstances in which the program evaluation includes all three components, the *complete design*. There are, in fact, two different cases when this might occur. One case is what Astin and Antonio (2012) term a *true experiment*. Similar to a scientific experiment that might be done in a research laboratory, this case compares the impact of an intervention on one data set with a control data set in which no (or only predictable) changes are expected. Participants would be drawn from a homogenous sample and then randomly assigned to the intervention or to the control setting (e.g., Hulleman and Harackiewicz, 2009). The measured outcomes, therefore, would be reasonably ascribed to the result of the intervention. Astin and Antonio (2012) point out that these conditions are extremely difficult to achieve, let alone reproduce, in educational settings. Instead, they suggest that the second case is much more attainable, a so-called *natural experiment*.

In a natural experiment, the purpose would also be to investigate the impact of an intervention. The notable difference, though, is that there is not a random assignment of participants to receive the intervention. Multiple environmental variables can be investigated simultaneously and individual differences are tracked, so the outcomes, therefore, can be assessed through multivariate statistical analyses. A reader may plausibly conclude from this mention of statistical analysis that the IEO model requires a study to be quantitative in nature. Astin and Antonio (2012), however, assert that the model may be used effectively with qualitative studies as well; for an example, the reader is encouraged to review Sriram and Diaz (2016).

These two complete designs for program evaluation contrast with the cases that have only one or two of the IEO components, collectively referred to as *incomplete designs*: I and O only; E and O only; E only; and O only (Table I). Astin and Antonio (2012) note that the ability to interpret the outcomes for these different incomplete designs must be qualified by the assumptions that come from excluding one or more of the IEO components.

Methods of Analysis

The coding scheme for this portion of the review is derived from the different categories within the IEO model, and the definitions come largely from the descriptions by Astin and Antonio (2012; Table I). Our main modification was to note the presence of any social, cognitive, or psychological theory included within the description of the collected data regarding the experiences or outcomes of the project.

Two of the authors of this literature review (LaDue and Callahan) discussed the different IEO categories described in Astin and Antonio (2012) and evaluated one manuscript to discuss how it might be classified. The two authors then separately coded the same five additional papers. After discussing areas of agreement and disagreement that emerged in the coding, they divided the IEO category into two separate classes. First, we denoted natural experiments as "IEO Exp" in Table I. Second, we recognized a need to create a category that was not described by Astin and Antonio: we needed to account for studies that included data related to input, environment, and output but did not include either a control group or random assignment; this class is denoted as "IEO" in Table I. We ultimately did not create a class for true experiments since none of the reviewed papers fit that description.

The two authors then separately coded an additional four papers. Comparison of coding revealed complete agreement. One author (LaDue) then proceeded to code the remaining papers using definitions in Table I.

Six of the 45 papers reviewed did not fit within the categories in our coding scheme; these papers were more general commentaries related to diversity in the geosciences or other studies that did not explicitly summarize projects aimed at broadening participation in the discipline. For example, one paper included Hispanic students as a study population but the focus of the research was not on recruitment and retention (Martinez et al., 2012). Another five papers were related to questions about increasing diversity, but were not a summary of a specific project or program. An example from this subset is the Levine et al. (2007) pipeline model; obviously, this paper is highly relevant, but it was nonetheless not suitable for analysis using the IEO categories. In sum, 11 papers were excluded from further analysis. In total, 34 papers are included in the analysis; these references are listed in an online supplement (Appendix A; available in the online journal and at <http://dx.doi.org/10.5408/16-238s1>); similarly, a summary of the coding of the 34 papers is also available in an online supplement (Appendix B; available in the online journal and at <http://dx.doi.org/10.5408/16-238s2>).

Findings

Before discussing the results for the different IEO categories, we provide a couple of examples of how we coded papers using the IEO model. Hammersley et al. (2012) was classified as an IEO natural experiment. In an effort to recruit additional Hispanic students to the geosciences, Hammersley et al. (2012) redesigned an introductory geology course to include place-based examples that focused on the geology of Mexico. To evaluate whether this course was successful, the authors compared the knowledge and attitude gains of Hispanic and non-Hispanic students enrolled in the Geology of Mexico course (i.e., the intervention) to those enrolled in the more traditional Physical Geology course (i.e., the control). Students enrolled in each class completed a knowledge test and an attitudes survey before starting the course; this can be considered the input (I component) according to the IEO model. The authors described in detail how the course design differed from the traditional one. The main program element, or environment (E), tested in this study was the use of place-based laboratory activities based in Mexico as compared to traditional laboratories with a variety of places represented. Finally, after the course, the students completed the same knowledge test and attitudes survey in order to evaluate the outcomes (O). Statistical analysis of the pre- and post-measures showed knowledge gains for White/Asian students enrolled in the Physical Geology course ($p < 0.05$) and Hispanic students enrolled in the Geology of Mexico course ($p < 0.0001$). Additional analysis of institutional data showed that Hispanic students enrolled in the Geology of Mexico course were more likely to take subsequent geology courses than students enrolled in the Physical Geology course. Hammersley et al. (2012) offers a clear example of how utilizing the IEO framework can provide evidence that a specific intervention is effective. Their incorporation of a natural experiment, in which students in a control group are compared to the intervention group, strengthens the claim that the gains were caused by the intervention and not by some other factor.

For comparison, Pride and Olsen (2007) provide an example of an "E and O only" paper, while Riggs et al. (2007) provide an example of an "E only" paper. In Pride and Olsen (2007), the summary explains that the program involved training and providing opportunities for URM marine science majors to engage with K–12 schoolchildren, hence fulfilling the E component of the IEO model. The outcomes (O component) are summarized in terms of the number of science majors who have gone on to pursue other volunteer or career opportunities in teaching science. Riggs et al. (2007) detail a multistage program to recruit and retain Native American students in the geosciences. In their conclusions, the authors state that "until we mentor one student through all four components of the program, we do not feel fully comfortable using the word 'successful' " (Riggs et al., 2007, 484). Both summaries, though, have a sufficiently rich description of their programs for those who may be interested to develop similar initiatives. The IEO categories draw attention to the fact that these summaries do not emphasize evidence to support the impact of the environment. However, we also note that the authors are not making such claims either.

In looking over the results for the coding of the 34 papers, we see that there is at least one of each code in Table

TABLE II: Classification of articles in the 2007 JGE special issue, *Broadening Participation in the Earth Sciences*, and between 2009–present.

Category	2009–Present		2007 Special Issue	
	%	No.	%	No.
Environment (E)	17	3	25	4
Outcome (O)	6	1	6	1
Environment–Outcome (EO)	22	4	44	7
Input–Environment–Outcome (IEO)	33	6	19	3
Input–Environment–Outcome—Experiment (IEO-Exp)	22	4	6	1
Total Number of Papers		18		16

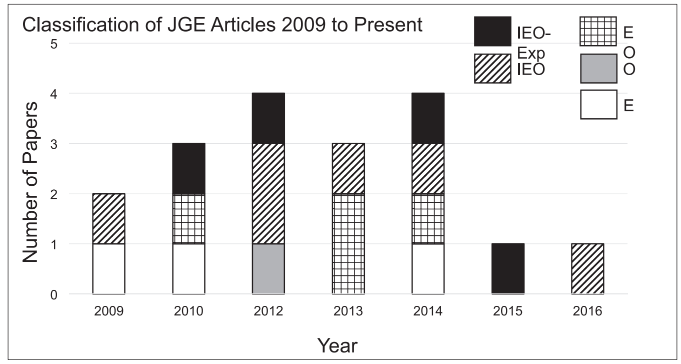

FIGURE 2: Classification of articles in JGE issues from 2009 to present based on different designs of the IEO model.

I except for the "I and O only" category (Table II). In other words, all but two of the 34 papers included an environment component within their data collection and analysis.

The majority of the 17 papers from the 2007 special issue of JGE were coded into one of the incomplete IEO research design categories (Table II). Since 2009, there have been more complete IEO research design studies, although not as many as one per year (Fig. 2). From 2007 to the present, there are roughly three papers per year published related to recruitment and retention programs for URM in the geosciences, and there is a shift over time in the design of studies from incomplete to complete (Fig. 2).

Finally, relatively few papers integrate cognitive, social, or psychological theories into their discussion of different programs. One exception is Baber et al. (2010), which addressed self-efficacy in the summary of a summer research experience meant to recruit and retain URM students; the summary was categorized as an IEO-natural experiment. Another example is Stokes et al. (2007), which included the construct of critical incidents as part of the basis for an education outreach program; this was also identified as an IEO-natural experiment.

Discussion

One of the noticeable outcomes from this analysis is the unevenness of the different IEO categories. Many of the summaries do not incorporate data about the students' backgrounds. This means the studies lacked the *Input* component of the programs; consequently, claims about the success of such programs are not, in fact, built upon an understanding of the characteristics of the students who benefited from them. We see in the examples of Pride and Olsen (2007) and Riggs et al. (2007) that this may not have been the intent. It is also evident from the data that many of the past summaries have provided information about the nature of the environment for a given program, yet relatively few of these descriptions have been guided by a cognitive, social, or psychological theory. Thus, although programs may offer some postintervention data, there is not a clear or deep understanding of why or how they benefit the participants.

In looking at the categories of studies over time, we notice that there may be a shift underway from more incomplete designs to complete designs. We propose two possible explanations for this shift. First, by 2010, initial projects funded through the NSF program, OEDG, were ending and in a position to publish more complete evaluation data. The NRC (2013) report on preparing the next generation of Earth scientists noted that many of the projects funded through OEDG included significant evaluation data, often built upon logic models. A second possible explanation for the shift is that, by 2010, the editorial team of JGE led by Dr. Julie Libarkin implemented several strategies with the intent to position JGE as the premier journal for geoscience education research literature. In 2009, the journal established separate Curriculum and Instruction and Research categories to encourage geoscience education research faculty to publish experimental and theoretical papers that would be distinct from manuscripts identified as scholarship of teaching and learning (Libarkin et al., 2009). In 2010, the journal increased its visibility still further by making published articles available online in addition to hard-copy print editions (Libarkin, 2010). These efforts have been continued as editorship transferred from Libarkin (Libarkin and St. John, 2011) to Dr. Kristen St. John (St. John and Libarkin, 2011; St. John et al., 2016). Combined, these efforts may be contributing to an apparent shift in the nature and quality of studies included in this review.

Summary

We reviewed past studies on broadening participation in the geosciences by employing the IEO model as a framework. Through the presence or absence of inputs, environment, and outputs in each study, the IEO model highlights the extent to which recommendations for successful strategies are informed by students' lived experiences. In our review, we found that few studies have truly coupled recommendations with an investigation of why and how a given strategy was successful.

Our argument for the use of the IEO model in studies related to recruitment and retention of URM to STEM fields is not a novel idea; we identified several studies from other STEM disciplines that incorporated the IEO model into their research design (e.g., Cole and Espinoza, 2008; Whalen and Shelley, 2010; Johnson, 2012; Alkhasawneh and Hargraves, 2014; Strayhorn et al., 2014; Sriram and Diaz, 2016). Of these, most were quantitative in nature and generally sought to develop predictive models. Outcome variables included the retention of URM students in STEM majors (Whalen and Shelley, 2010; Alkhasawneh and Hargraves, 2014), academic performance of Latino students in STEM (Cole and Espinoza, 2008), sense of belonging for racially diverse women in STEM majors (Johnson, 2012), and benefits of interactions with diverse peers in an engineering program (Strayhorn et al., 2014). Using a qualitative approach, Sriram and Diaz (2016) incorporated the IEO framework into a phenomenological study on the experiences of undergraduate students of color in STEM learning programs. All of these studies generally align with the Astin and Antonio (2012) description of a natural experiment. As explained by Whalen and Shelley (2010), "in using [the IEO model], the study explores student background, student financial situations, and institutional variables to assist in developing a theoretical model that helps better understand the complexities of the college completion process" (47).

Furthermore, these studies also provide examples of how to couple the ideas of input, environment, and output with other theoretical frameworks (e.g., Cole and Espinoza, 2008; Alkhasawneh and Hargraves, 2014). In such cases, the programmatic efforts to support students in STEM were explicitly considered from the perspective of a theory that drew attention to an aspect of students' experiences. This brings us to another observation from our review studies in JGE: few papers situated their studies in a cognitive, social, or psychological theory. Interventions related to broadening participation can be greatly strengthened by making connections to existing theories because they provide a means to explain and predict aspects of students' experiences as well as to understand the outcomes. The remainder of this review departs from what we know about increasing diversity in the geosciences to explore what we know about why and how certain strategies are successful in increasing diversity in STEM fields more generally.

THEORETICAL FRAMEWORKS ON BROADENING PARTICIPATION IN STEM

In this section, we describe theoretical frameworks that provide insights into the lived experiences of URM students and those that are useful for developing interventions or designing studies aimed at broadening participation in the geosciences. We included the following theoretical frameworks: *self-efficacy*, *identity*, *microaggressions*, *stereotype threat*, and *social cognitive career theory*. Four authors (Baber, Sexton, van der Hoeven Kraft, and Zamani-Gallaher) reviewed studies to identify an initial list of 12 theoretical frameworks that serve as foundations for investigating access and success of URM in STEM. The group reviewed the initial list of 12 frameworks and reduced the list to the five included in this paper. The list was reduced so that the theories could be described in sufficient detail. The five selected met the following criteria: (1) there was a large literature pool describing the development and application of the framework, (2) a large number of studies and articles have been published that apply the frameworks to understanding access and success of URM, and (3) at least one author of this paper has used one of the frameworks personally.

For each theory, we provide a discussion of its background, its definition, and a discussion of how the theory may influence efforts to increase diversity in geoscience (Table III). The intent is not to present an exhaustive list of relevant theories. Nor is the intent to identify gaps in the literature or future research questions related to these theories. Instead, we emphasize that our goal is to draw attention to theories that have been used to design interventions to promote diversity as well as to conduct research investigating how to increase diversity.

The following subsections refer to study participants based on their race and ethnicity. As of 1997, the revised standards for federal race and ethnicity reporting require a minimum of five categories for race: American Indian or Alaskan Native (AIAN), Asian, Black or African American, Native Hawaiian or Other Pacific Islander (NHPI), and White, and two categories for ethnicity: Hispanic or Latino/a or Not Hispanic or Latino/a (U.S. Office of Management and Budget, 1997). Consequently, in the text that follows, we will use the terms Black, White, and Hispanic, regardless of whether the original authors used those terms or alternative terms based on the federal guidelines.

Self-Efficacy

Background on Theory

Self-efficacy is confidence in one's ability to accomplish different tasks (Bandura, 1986). A strong sense of efficacy boosts personal well-being and allows individuals to approach difficult tasks as challenges to be mastered (Bandura, 1986, 1997). Self-efficacy can be fostered through four sources (Bandura, 1986). The strongest source of self-efficacy is direct experience, called enactive mastery experience (Bandura, 1986). When an individual engages in an activity and experiences success, then self-efficacy related to that activity can be fostered. Individuals can vicariously increase self-efficacy if they see someone else successfully complete a task, which fosters a belief that they also can complete that task (Bandura, 1986). A third source of self-efficacy comes from verbal persuasion, when individuals are persuaded by others that they possess the capabilities to master given activities they are more likely to sustain those efforts. A final source of self-efficacy comes from individuals' interpretations of their physiological and emotional state when engaging in an activity. For example, suppose someone experiences a racing heart and sweating while anticipating and engaging in an activity. If that individual has a negative interpretation of those physiological cues as indicators of failure, then self-efficacy is weakened. If, however, that individual has a positive interpretation of those cues as components of successful performance, then self-efficacy is strengthened.

Application to Program Design

Self-efficacy is an important factor associated with a student's selection of an academic and career path and has been used to understand recruitment and retention of URM students in STEM. For example, Black male STEM majors described the importance of their self-efficacy in completing course work and on persisting in their STEM disciplines (Strayhorn, 2015). Many factors have been shown to promote URM self-efficacy in science (e.g., Zeldin et al., 2008). Instructional interventions and experiences can enhance students' self-efficacy (Luzzo et al., 1999; Garcia, 2010). Luzzo et al. (1999) implemented targeted instructional interventions that increased students' self-efficacy in science. Role models or mentors who offer encouragement as well as advice on different academic and career paths can enhance

TABLE III: Summary of theories that could be applied to studies on recruitment and retention of URM in the geosciences.

Theory	Background	Application
Self-efficacy	Self-efficacy is confidence in one's ability to accomplish academic tasks (Bandura, 1986).	Examples of factors to promote URM self-efficacy in science include: instructional interventions and experiences, mentored research experiences, and access to role models (Luzzo et al., 1999; Hurtado et al., 2009; Baber et al., 2010; Garcia, 2010; Chemers et al., 2011; Fraze et al., 2011; Garriott et al., 2013).
Identity	Identity development occurs through interactions between an individual's characteristics, dimensions of identity, and context (Jones and McEwen, 2000).	Challenges for URM students developing science identity can include perceived conflict with racial identity (Fordham, 1985; Ogbu and Simons, 1998), access to information (Harackiewicz et al., 2012), and need to represent a minority group (Carlone and Johnson, 2007; Hurtado et al., 2009; Reyes, 2011).
Microaggressions	Microaggressions are subtle forms of discrimination (verbal and nonverbal) that occur daily, are so frequent, and understated that they are unrecognizable by perpetrators in their interactions with members of diverse marginalized groups (Sue, et al., 2007; Sue, 2010a, 2010b).	Race-related stresses resulting from microaggressive incidents reflect the ongoing impact of subtle and overt discrimination, which creates a racial battle fatigue (RBF; Smith et al., 2007; Smith, 2010; Smith et al., 2011).
Stereotype threat	Stereotype threat occurs when individuals feel pressure to perform and avoid confirming a negative stereotype about one's group (Steele and Aronson, 1995).	Stereotype threat can lead to a lowered performance if an individual ends up being characteristic of stereotype, which then can further undermine students' beliefs about their abilities and perceptions of their identity (Steele, 1997, 2010; Woodcock et al., 2012).
Social cognitive career theory	An individual's interest in, selection of, and persistence in academic and career paths are influenced by a complex interplay of cognitive-personal and contextual factors (Lent et al., 1994).	Self-efficacy, influence of mentors, social connections within, and knowledge of the community can influence the decision to choose STEM-related major and career (Quimby et al., 2007; Ovink and Veazey, 2011; Garriott et al., 2013; Lent and Brown, 2016).

URM students' self-efficacy (Hurtado et al., 2009; Baber et al., 2010; Chemers et al., 2011).

Engagement in original research has mixed results on increasing self-efficacy for URM students. Mentored research experiences can promote URM self-efficacy by building students' confidence in engaging in scientific work (Hurtado et al., 2009; Chemers et al., 2011). Alternatively, some URM students who participated in mentored research reported no increase in self-efficacy, and, in some cases, increases in self-efficacy occurred only when specific programmatic conditions existed (e.g., the mentored research program occurred for an extended period; Baber et al., 2010; Carter, 2011). These findings suggest that, as students persist through multiple contexts, the development of self-efficacy is both varied and fluid.

A distinction exists between some studies that is worth making explicit—and will be seen again with other theories. In some cases, self-efficacy is identified as a mitigating factor related to persistence in STEM (e.g., Strayhorn, 2015). In other cases, the purpose is to investigate if a particular intervention or program has had an effect on increasing students' self-efficacy (e.g., Baber, 2010). This distinction can be further understood in terms of the IEO model. For example, if the goal is to identify the extent to which self-efficacy (I) contributes to persistence in a STEM major (O) as a result of participation in a program (E), then this will require identifying students' levels of self-efficacy prior to intervention (i.e., input). If the goal of a study is to understand the impact of a program (E) on self-efficacy (O), this will require identifying students' levels of self-efficacy prior to the intervention (I) as well as after it. In the former example, one might group the participants into high and low self-efficacy categories (I) and test group differences in persistence in STEM (O) after participating in a program (E), while the latter would look at changes in self-efficacy scores before (I) and after (O) participating in the program (E). Across these studies, self-efficacy is commonly measured through surveys but can also be further explicated through qualitative interviews (e.g., Baber et al., 2010).

Identity

Background on Theory

Formation of student science identity occurs through interactions between individual and sociocultural factors (Jones and Abes, 2013). Science identity development is the result of interactions between three main components: the *core*, *dimensions of identity*, and *context* (Jones and McEwen, 2000). The core component includes the inner self and is defined by personal attributes and characteristics that individuals incorporate into their everyday life. The core is influenced by different dimensions of identity, which include, but are not limited to, conceptions of race, culture, socioeconomic background, gender, religion, and sexuality, and which may be continuously contested and (re)defined by social assumptions and norms. These assumptions and norms are in turn influenced by context, which includes different social experiences such as family background, schooling experiences, and other sociocultural conditions.

Application to Program Design

Assisting underrepresented students to construct a scientific identity involves more than helping them navigate coursework (i.e., their context). For instance, to persevere, URM students must develop strategies to see their identity as a scientist as just one dimension of their identity. It is of concern for some students that racial identity can sometimes be in direct conflict with an academic identity (Fordham, 1985; Ogbu and Simons, 1998). In other words, anyone who is encouraging students to develop a scientific identity must be equally intentional about acknowledging that students carry multiple dimensions of identity and not ignore other aspects of the students' sense of self.

Yet the picture is still more complicated. When thinking about science (or geoscience) as a community of practice (Lave and Wenger, 1991), we find identity is an important aspect of how one becomes part of that culture (Carlone and Johnson, 2007). In order to obtain a scientific identity, one needs to have the knowledge of how to express oneself with the appropriate language, to dress and to interact within the given community, and to nurture a desire to be a part of that culture (Lave and Wenger, 1991; Carlone and Johnson, 2007; Callahan et al., 2015). Furthermore, Carlone and Johnson (2007) argue that creating a scientific identity requires not only competence and interest but also an awareness that there are various professional pathways into the discipline. For example, Harackiewicz et al. (2012) provided information pamphlets to families whose members did not have college educations about how to talk to their adolescents to explain why math and science are useful future career options. This new information had nearly the power of another commonly cited factor, a mother's educational level, to predict whether students would enroll in high school STEM courses.

In terms of the IEO model, we see again variation in how theory is integrated into the research design. For example, scholars have examined the influence of campus engagement on identity development for URM students (Baber, 2010; Quaye and Harper, 2014). In such cases, students' sense of identity can be both an input and output, while their experiences in a given setting constitute the environment component. Similar to self-efficacy, identity can be described through quantitative measures such as surveys (e.g., Chemers et al., 2011) or qualitative methods such as semistructured interviews (e.g., Tate and Linn, 2005). A different research design could focus on the role of URM students' sense of identity on their perceptions of experiences in STEM majors (Tate and Linn, 2005; Charleston et al., 2014). Identity is still an input and experiences in a setting comprise the environment, but the output could be qualitative, such as a synthesis of how students make sense of their experiences, or could be quantitative, as reflected by persistence.

Microaggressions

Background on Theory

Microaggressions are everyday forms of discrimination experienced particularly by people with disabilities, people of color, women, and Lesbian, Gay, Bisexual, Transgender, Queer, Intersex, and Asexual (LGBTQIA) persons. As with most of this review, however, we concentrate on literature related to microaggressions as experiences of URM. Microaggressive behaviors generally are enacted by individuals who are members of the dominant culture. Examples of microaggressions include, but are not limited to, questioning the qualifications of stigmatized and marginalized groups, being dismissive of their presence, disregarding their feelings and experiences due to perceived deficiencies, or group disapproval.

Microaggressions take three forms: microassaults, microinsults, and microinvalidations (Sue et al., 2007; Sue, 2010a, 2010b). Microassaults occur when there is a willful effort to hurt or harm an individual by using negative racial or ethnic epithets as well as when there is explicit promotion of racial antipathy through verbal or nonverbal attacks. Microinsults are typically insensitive remarks, rude behavior, and demeaning comments about an individual's racial background; they are thought to be "slight" snubs made unwittingly by the perpetrator (Sue et al., 2007). Microinvalidations are communications that are intended to be exclusionary, to disaffirm, or to invalidate the experiences, feelings, and thoughts of people of color or other marginalized groups (e.g., women, persons with disabilities, and LGBTQIA).

The extant literature is replete with research and examples of racial microaggressions. The term *racial microaggressions* was coined by psychiatrist Chester Pierce to describe what culprits considered as harmless or mild offenses toward Blacks that were actually experienced as egregious humiliations based on race (Pierce, 1970). Pierce noted racial microaggressions were "designed to reduce, dilute, atomize, and encase the hapless into his 'place.' The incessant lesson the black [sic] must hear is that he is insignificant and irrelevant" (Pierce, 1969, 303). Hence, whether intentional or unintentional, microaggressions are prone to occur in interracial encounters, with people of color on the receiving end of racialized negative slights.

Application to Program Design

Racial microaggressions are understood to be brief and commonplace indignities even though their impact is long-lasting. Whether racial microaggressions are intentional or unintentional, the repeated racial slights, negative disdain, insults, and hostile environments inflict cumulative wounds on people of color.

On college campuses, targets of racial microaggressions are not restricted to students, but also include faculty and administrators of color, particularly at predominately white institutions (PWIs). Specifically, when considering the experiences of diverse students, there is an "invisibilizing" of students of color that exemplifies the racialized realities, both in and out of classrooms (Shotton et al., 2013). Racial battle fatigue (RBF) typifies the result of racial microaggressions in postsecondary education (Smith, 2010). RBF deals with the physiological, psychological, and behavioral strains imposed on people of color because of microaggressions (Smith et al., 2007; Smith, 2010; Smith et al., 2011; Karkouti, 2016). For example, in STEM departments where students, faculty, and administrators from racially or ethnically diverse groups are few, there can be lingering environmental conditions that produce and exacerbate RBF among people of color (Solórzano et al., 2000; Smith et al., 2007; Smith, 2010; Burt et al., 2016); RBF can lead to loss of focus, academic and social withdrawal, as well as premature departure from STEM degree programs.

Microaggressions differ somewhat from self-efficacy and identity in that the latter two are aspects of an individual personal development. Microaggressions are experiences that impact the individual and affect whether the individual selects and remains in science academic and career paths. With respect to the IEO framework, microaggressions are aspects of environment. This has implications for research design. For example, Burt et al. (2016) detail microaggressions of faculty advisors against Black male graduate students in an engineering program. The output includes findings that document the psychological and health-related impacts of microaggressions on the student, among them, difficulty in developing an identity as an engineer. Moreover, one of the recommendations for addressing microaggressions would be to implement cultural competency training for faculty. Naturally, subsequent study could investigate if an intentional effort for change in environment had an impact on students' experiences with microaggressions as well as their sense of identity or even self-efficacy.

Stereotype Threat

Background on Theory

Stereotype threat is "the social-psychological threat that occurs when one is in a situation or doing something for which a negative stereotype about one's group applies. This predicament threatens one with being negatively stereotyped, with being judged or treated stereotypically, or with the prospect of conforming to the stereotype" (Steele, 1997, 614). Stereotype threat is also related to identity and self-efficacy. For women and people of color, performance is negatively impacted by demeaning stereotypes based on their social identity; this has been evident in academic underperformance especially on high-stakes tests and in fields such as STEM (Steele and Aronson, 1995, 2004; Steele, 1997, 2010).

Steele (1997) found that the performance of stereotyped students dropped when the intelligence of those students was being evaluated. By contrast, when students were in situations deemed nonevaluative and absent of stereotype threat, student performance improved. Repeated experiences with stereotype threat led students to feel undervalued and prompted negatively stereotyped groups to disengage and disidentify with academic achievement in particular domains, and possibly with school in general (Steele and Aronson, 1995; Levy, 1996; Croizet and Claire, 1998; Cadinu et al., 2005; Steele and Ambady, 2006; May and Stone, 2010). Additionally, students experiencing stereotype threat receive lower scores on standardized tests than underrepresented students generally. In short, when individuals are at risk of confirming a negative stereotype assigned to a group to which they belong, negative emotions can derail their performance when they feel their performance is likely to be judged unfairly (Steele and Aronson, 1995).

Application to Program Design

Negative stereotypes have contributed to the underrepresentation of racial minorities in the STEM pipeline and specifically within the geosciences (Huntoon and Lane, 2007; Levine et al., 2009; NRC, 2013). Woodcock et al. (2012) found that Hispanic students who experienced stereotype threat during a three-year period expressed a diminishing interest in majoring in science; this example illustrates domain disidentification. Consequently, stereotype threat is situational but can be mediated through cultural experiences that fuel positive attitudes about identity.

There is variation with respect to individuals' vulnerability to stereotypes when considering aspects of identity alongside contextual factors such as type of institution and major area of study. Classroom and campus experiences for racial or ethnic minorities in STEM differ from their White peers; students of color at PWIs report hostile hallways and chillier institutional climates (Cabrera and La Nasa, 2001), while students attending historically Black colleges and universities (HBCUs), for instance, are found to perform better and persist in STEM programs (Palmer and Maramba, 2013). HBCUs offer a protective factor that fosters self-efficacy and counters negative stereotypes with respect to racial identity and minoritized status. Thus, there is a cultural congruency of fit between the person and the environment at minority-serving institutions that bolsters students' identity and their beliefs about their ability to do well in and out of class (Aragon and Zamani, 2002).

From the perspective of the IEO model, stereotype threat theory addresses all three components: input, environment, and output. The literature makes clear that URM students interested in STEM disciplines, including the geosciences, are likely to encounter and have to cope with stereotype threat (environment). Similar to microaggressions, experiences with stereotype threat are cumulative as well as corrosive to students' sense of interest and identity in STEM (output). A challenge, though, is that students entering a new environment (e.g., a given science department) will very likely have already accumulated experiences with stereotype threat (input). Indeed, students' risk for stereotype threat is sometimes measured using the stereotype vulnerability scale (e.g., Woodcock et al., 2012).

Finally, there are recommendations for reducing stereotype threat for students. Steele (2010) makes several suggestions, and one especially could be of value for the geosciences: "By changing the way you give critical feedback, you can dramatically improve minority students' motivation and receptiveness" (216). In particular, URM students were not particularly helped by either neutral feedback or feedback prefaced by positive assurances. Instead, the most meaningful feedback occurred when the instructor "explained that he 'used high standards' in evaluating [and] he believed the student could meet those standards" (163). For someone interested in further research or implementing an intervention, changing feedback would constitute a change in the environment; the success of this change could be assessed, perhaps by studying students' self-efficacy and identity (input and output), to determine if the adjustments had an impact.

Social Cognitive Career Theory

Background on Theory

According to social cognitive career theory (SCCT), an individual's interest in, selection of, and persistence in academic and career paths are influenced by a complex interplay of cognitive-personal factors (e.g., interest and self-efficacy) and contextual factors (e.g., role models and instructional experiences; Lent et al., 1994). The theory

TABLE IV: This table provides two examples of how the IEO model can be applied through an atheoretical approach (left) that takes a normative approach to participation in science and a self-efficacy theory-driven approach (right) that incorporates socio-cognitive theory to understand how the inputs and environment influence participation in science.

Model Component	Atheoretical Examples	Examples Related to Self-Efficacy Theory
Input	Demographics ACT/SAT scores Concept pre-test	Family support Interpersonal confidence Interest in science
Environment	Program description	Role models Mastery experiences Peer support
Output	Program evaluations Concept post-tests Graduation rates	Resilience Managing stress Persistence

explains how an individual's self-efficacy and expectations about the outcomes of participating in science-related activities foster interest in science. Interest is a complex construct (van der Hoeven Kraft, 2017, this issue) but is a strong predictor of a student's selection of a particular academic and career path. A host of contextual factors can either negatively or positively influence self-efficacy, outcome expectations, and interest (Navarro et al., 2007; Mills, 2009; Lent et al., 2011; Lent and Brown, 2013). Examples of these factors include availability and quality of role models, instructional experiences, career networks, parental support, and discrimination (Lent et al., 2000, 2002).

Application to Program Design

Researchers have used SCCT in studies of student academic and career choices within science (Quimby et al., 2007; Byars-Winston and Fouad, 2008; Lent et al., 2011; Wang, 2013a, 2013b; Moakler and Kim, 2014) and to specifically investigate URMs' academic and career paths in science (Quimby et al., 2007; Lent et al., 2011; Garriott et al., 2013; Zebrak et al., 2013; Lent and Brown, 2016). While researchers often study the role of a single factor under the SCCT umbrella (e.g., self-efficacy) on an individual's selection of an academic and career path in science, they may also conduct studies that examine the interplay of multiple factors (e.g., self-efficacy, interest, goal orientation, and stereotype threat) on an individual's selection of an academic and career path in science (Lent and Brown, 2016).

Garriott et al. (2013) found that URM students were more likely to do well in class and have higher levels of self-efficacy when their parents encouraged them to do well. Austin (2010) noted that family encouragement in science and math positively predicted Black high school students' selection of a science or math career. Quimby et al. (2007) reinforced the importance of social supports for predicting URM students' interest in environmental science, but they also observed that URM students perceived more barriers to pursuing an environmental science educational and career path than did White students. Crisp et al. (2009) identified two contextual factors—the numbers of credit hours students were enrolled in during their first semester of college and whether they received Pell grant funding—that were not significant predictors of URM students' selection and persistence in STEM. Ovink and Veazey (2011) found that targeted instructional interventions (i.e., an educational contextual factor) could bolster URM students' social connections within the community and their knowledge of it, leading students to increase their understanding of possible career options and to feel more confident that they belong in science.

Like stereotype threat, input (e.g., self-efficacy), environment (e.g., institutional experiences like discrimination), and output (e.g., career decisions) are all embedded within SCCT. As a result, research design for studies based on SCCT employ a suite of techniques to capture the interactions between these three components; this is well explained by Quimby et al. (2007):

> *''In our study, we examined the social cognitive features that contribute to students' interest in environmental science to identify and better understand the reasons why certain ethnic and racial groups are underrepresented in environmental career fields. We administered measures of cognitive (self-efficacy, outcome expectations, environmental attitudes), environmental (role model influences, social supports, and barriers), and outcome (interest in environmental science) variables to undergraduate students. . . . Based on SCCT propositions, we hypothesized that the predictor variables, individually and collectively, would predict significant variance in students' interest in environmental science.''* (44–45)

Many studies using SCCT as a framework have gathered quantitative data to measure input, environment, and output; however, qualitative studies are also possible with SCCT as a framework. As a starting place, researchers could include measures of self-efficacy and interest (which can be considered both inputs and outputs depending on the program or study goals), barriers and supports (which are aspects of the environment), and intent to pursue a science major (an output).

Summary

One observation from the literature review in the first part of this paper is that there were few instances of interventions in geoscience situated in cognitive, social, or psychological theories. Instead of merely advocating for the use of theories, we described theories to demonstrate how they provide specific insights into the lived experiences of students. For those interested in designing initiatives or making changes to broaden participation of URM in the discipline, theories can help them understand why and how different programmatic elements or actions are beneficial. Our hope is that this review has demonstrated the importance of choosing a theoretical framework prior to, and not after, implementing an intervention or research study.

To argue this idea further, we compare two hypothetical research designs: one typical of the past publications on broadening participation in the geosciences and one based upon self-efficacy (Table IV). Suppose we assume that both approaches incorporate input, environment, and output elements. Will the resulting findings be equally compelling in terms of the benefits for the lived experiences of URM students? Input variables, such as demographics and test scores, and output variables, such as post-test scores or graduation rates, are certainly valuable for documenting program effectiveness. Yet, these data sources tend to place a greater focus on the quantitative measures of success rather than qualitative descriptions of success. Contrast this with a study based on self-efficacy. Input and output variables would provide a detailed image of students' perspectives. Thus, a theory-driven approach that focuses on cultivating resilience and persistence in science helps explain how and why a program increases participation in science.

CONCLUSIONS

One of the central suppositions guiding this literature review is that educational theories help to accumulate evidence about different problems. Indeed, Shavelson and Towne (2002) argue:

> *''It is the long-term goal of much of science to generate theories that can offer stable explanations of phenomena that generalize beyond the particular. Every scientific inquiry is linked, either implicitly or explicitly, to some overarching theory or conceptual framework that guides the entire investigation. Science generates cumulative knowledge by building on, refining, and occasionally replacing, theoretical understanding.''* (3)

The first part of this review uncovers a subtle shift in the diversity publications towards studies that include the complete IEO model. This may indicate a shift toward building evidence of why specific interventions work, rather than simply making an effort to increase participation of URM in geoscience. 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.

The second part of this review identifies several theories that offer tools to fortify future interventions and studies aimed at broadening participation in the geosciences. Implicit in our argument is that theories need to be incorporated into program development from the outset. Using this approach enables the community to build the knowledge base about not only *what* works but also *why* it works, and for *whom*. We encourage the reader not to be overwhelmed by the prospect of incorporating theories into interventions or studies. Instead, consider identifying a particular theory as a central target of inquiry. Other theories will undoubtedly intersect, but they can be supplementary; we do not mean to suggest that a particular study needs to consider all reviewed theories simultaneously.

Broadening participation in the geosciences is not a problem that can be solved simply by creating a critical mass. The problem is more nuanced and is intertwined with individual and environmental factors (e.g., identity, micro-aggressions). Indeed, in Astin's initial discussion of the IEO model, he draws upon his early experiences in medical settings and recalls that measuring the effectiveness of a treatment required a thorough understanding of the patient's condition at the outset (Astin and Antonio, 2012). This means not only drawing upon the extant literature about URM students in higher education, generally, but also reflecting deeply on the culture of the geosciences. Educational theories provide a lens, a mechanism, for digging deeper into how our community functions as a collective. First, though, we need more scholars to implement these theories and give voice to the experiences of those who are still underrepresented in the sciences.

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