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Extreme underrepresentation of first-generation college students in the geosciences: An intersectional issue

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ABSTRACT

First-generation college students (FGCS), defined as students whose parents did not earn a baccalaureate degree, encounter distinct obstacles navigating academia. Barriers faced by FGCS, including lack of financial security, lower sense of belonging, and inadequate mentorship, are often compounded by the intersection of other marginalized identities. As such, efforts to improve diversity, equity, and inclusion can and should include FGCS. To better support FGCS, first we must fully understand who they are, where they are pursuing degrees, what they choose to study, and their representation in the geosciences. We use over 40 years of data to explore the demographics and field of study of FGCS in U.S. institutions. We observe that FGCS have outnumbered non-FGCS at the undergraduate level since data collection began in the 1990's. At the doctoral level we present data from 1974–2016 that show that although non-FGCS have outnumbered FGCS since the 1990's, most doctoral graduates of color continue to be FGCS. Our data also show that in 2016 over 61% of all undergraduates receiving a bachelor's degree across all fields were FGCS, 54% of physical science undergraduates were FGCS, and yet only 25% of those in the geosciences were FGCS. Out of the various fields analyzed, the geosciences have the lowest percentage of FGCS at the undergraduate *and* doctoral level. This begs the question, why are FGCS yet another markedly underrepresented group in the geosciences? Here we begin to address this question and provide guidance for how to reduce barriers to FGCS inclusion in the geosciences.

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Introduction

Low diversity within the geosciences has been a persistent concern for decades (Gillette, 1972; Malcom et al., 1976). Research shows that including people with different perspectives and life experiences produces more creative solutions to problems and leads to a higher level of scientific innovation (Roehling et al., 2005; Sherman-Morris & McNeal, 2016). However, as Haacker and others (2020) argue, institutions should move away from treating efforts in diversity, equity, inclusion, and justice as a business decision as it fails to acknowledge the paramount moral rationales for this work and the responsibility institutions have for dismantling discriminatory structures. Increasing diversity in the geosciences has largely focused on gender and race/ethnicity, but diversity extends beyond these social constructs. Here we argue that first-generation college students (FGCS) are a diverse group and increasing their representation in the geosciences has the potential to increase diversity in various ways and push the field toward a more equitable future.

Previous literature on FGCS has broadly characterized who FGCS students are and has identified the challenges

they face when pursuing higher education. FGCS are more likely to come from low-income families, be older, and have dependent children than non-FGCS (Núñez, 1998; Schademan & Thompson, 2016; Terenzini et al., 1996). They are often not taught essential information about postsecondary education, such as navigating financial aid, the art of writing personal statements, and the application process (Pascarella et al., 2003). Their parents are unable to pass down generational knowledge on the “hidden curriculum” of higher education such as how to get an undergraduate research position, how to write an email to a professor, the importance of extracurriculars and leadership positions, how to build a professional network and more (Pensky et al., 2021). FGCS are more likely to have a problematic high school-to-college transition and do not have the tools or psychosocial support for navigating the college lifestyle (Pascarella et al., 2003; Terenzini et al., 1996). Studies suggest that FGCS encounter specific challenges when entering college, such as a lower sense of belonging and lack of awareness of unspoken academic norms (Means & Pyne, 2017). These studies also show that FGCS have had less academic opportunities and preparation upon entering college (Atherton,

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2014; Holland, 2010; Núñez, 1998) and take more remedial courses than non-FGCS (Gibbons & Woodside, 2014).

Historically, people from marginalized groups were prohibited from pursuing higher education due to their race, gender, religion, and/or socioeconomic status. Most laws intended to make education more equitable were enacted less than 100 years ago. For example, the landmark *Brown v. Board of Education* Supreme Court case that outlawed segregation in schools occurred in 1954, Title XI which prohibits discrimination on the basis of sex was signed into law in 1972, and Native American Boarding Schools were not fully shut down until the 1970s after they were declared a national tragedy in the 1969 Kennedy Report (Bear, 2008; Library of Congress, 2022; United States Courts, 2022). The effects of centuries of discrimination against marginalized groups are still present in today's academic structures. In 2014, approximately twice as many Hispanic, Native American, and Black undergraduate students were FGCS compared to non-FGCS, and women comprised 60% of FGCS undergraduate students, compared to 52.5% of non-FGCS (NCES, 2014). The historical exclusion of certain people from higher education has perpetuated a cycle of inter-generational poverty that disproportionately impacts groups with intersecting marginalized identities and the cycle is difficult to overcome without academic institutions being aware of past and present barriers that exclude marginalized groups.

Due to a combination of factors, FGCS are 71% more likely to leave college in their first year and have a lower 5-year graduation rate (13%) than their non-FGCS peers (33%) (Pratt et al., 2019; Próspero & Vohra-Gupta, 2007). Additionally, many FGCS experience family achievement guilt, similar to survivor's guilt, from which they feel guilty for the academic opportunities available to them and not others in their families. They may also face a lack of support or resentment from family members who feel like they are being left behind, which is particularly harmful for students whose main social support system is family. These challenges often lead to a lower sense of belonging in college and at home and are factors associated with greater risk of depression (Covarrubias & Fryberg, 2015; London, 1989; Whitten, 1993). Museus and Quayle (2009) studied the consequences of low FGCS retention rates and found that it resulted in reduced annual incomes, increased student loan debt, higher incarceration rates, decreased civic involvement, and more. These are long-term individual and societal consequences, and as Schademan and Thompson (2016) purport, U.S. colleges and universities have a responsibility to investigate ways in which institutional structures hinder first-generation, low-income students' success and increase support to better position them for career opportunities.

There is a significant body of FGCS literature, but additional research to broaden our understanding of FGCS and metrics to assess FGCS trends through time are still needed (Núñez, 1998; Pratt et al., 2019). Geoscience specific FGCS literature is even more limited and published data on demographics or trends through time does not exist to our knowledge. FGCS are a diverse population whose experiences within the geosciences are not often discussed.

Therefore, the questions motivating this research are: **Who are first-generation college students and what is their representation in academia? What fields are they choosing to study and at what institutions? And what is their representation within the geosciences?**

To address these questions, we have compiled multiple data sources to investigate the overall demographics and characteristics of U.S. FGCS, and more specifically, the proportion of FGCS in the geosciences (all data are available in the Supplement). Through this combined dataset, we demonstrate that the geosciences have largely failed at recruiting and retaining FGCS to a greater degree than other fields, which begs the question: Why is first-generation college student representation in the geosciences so low and how can we do better? We recognize the answers to this question are complex. The goals of this paper are to use FGCS statistics to bring awareness to the disparity in their representation in the geosciences, identify geoscience specific barriers for FGCS, and provide recommendations for increasing recruitment and retention of FGCS.

Who are first-generation college students (FGCS)?

The definition of "first-generation college student" matters

Before we can better understand who FGCS are, we first need to know who counts by definition. The Higher Education Act (USDE, 2014) defines FGCS as "an individual both of whose parents did not complete a baccalaureate degree" or, if the student was raised by only one parent, "an individual whose only such parent did not complete a baccalaureate degree." However, the Department of Education interprets first-generation status in at least three different ways: the legislative definition (no parent in the household has finished a bachelor's degree) and the two traditionally used for FGCS research (*no education* after high school or *no degree* after high school) (Sharpe, 2017). These definitions are rife with ambiguity, leading to institutions and individuals altering or supplementing their own addendums to this definition when determining FGCS status—adding considerations such as grandparent education, sibling college attendance, excluding those whose parents obtained an associate degree or have some college experience—which can lead to wildly different targeted groups for support. For example, using the definition from the Higher Education Act means that ~70% of undergraduate students could be classified as FGCS, meanwhile, using the definition used in previous FGCS literature (*no education* after high school), that number drops to ~20% (Supplement Figure 1).

It is thus important to clarify which definition is being used not only for the sake of statistics and data comparison, but also because each definition includes or excludes different groups of students. Lack of clarity on the definition of FGCS leads to confusion and misinformation among students, made worse by misguided comments or advice from peers, faculty, and administrators. For example, one of the authors was the first in their family to attend college and recalls being concerned that their younger brother

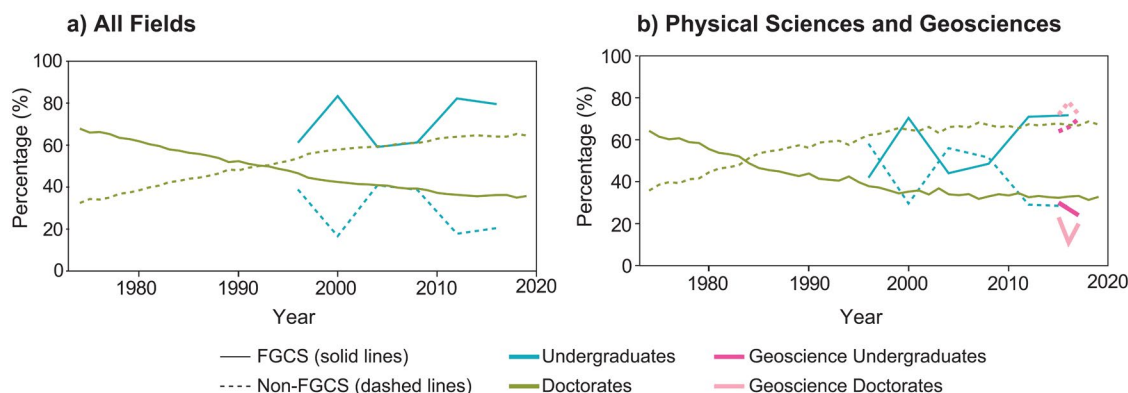


Figure 1. a) Percentage of FGCS (solid lines) and non-FGCS (dashed lines) undergraduate and doctoral graduates in all fields of study. b) Percentage of FGCS and non-FGCS undergraduate and doctoral graduates in the physical sciences and the geosciences.

would not qualify for FGCS scholarships and opportunities. Another author was told that FGCS were those whose parents did not have a *graduate* degree. For simplicity, we will use the Higher Education Act's definition for our discussion of FGCS data, which is also the definition the NSF uses when collecting data for the Survey of Earned Doctorates: an individual with no parent who finished a baccalaureate degree.

First-generation college student representation in academia by degree and field of study

Given the definition above, we first ask what proportion of students earning academic degrees are FGCS? From 1996 to 2016, the majority of graduates earning bachelor's degrees across "all fields" of study were FGCS, a trend that likely extends to before 1996 (Figure 1a). The proportion of FGCS in the physical sciences (a subgroup of all fields that includes geosciences, plus other disciplines) has been more variable through time with majority FGCS in some reporting periods and majority non-FGCS in others over the 10 years of data collection (Figure 1b).

The proportion of FGCS doctoral graduates in all fields and in the physical sciences has been steadily declining since the 1970s, with the number of non-FGCS earning doctorates surpassing FGCS about a decade sooner in the physical sciences (1980s) compared to all fields (1990s) (Figure 1). These trends show that even though more FGCS are earning bachelor's degrees, non-FGCS have been *disproportionately* earning doctorates for the past few decades. Why? The decline in FGCS receiving doctoral degrees could be attributed to the increasing cost of higher education, increasing barriers for applying to graduate programs, increasing importance placed on unspoken expectations for entering graduate school and succeeding in graduate programs, and/or a decrease in perceived value of doctoral degrees among FGCS.

There are only three years' worth of data for the geosciences (2015–2017), making direct comparison between datasets difficult. However, the data are striking. In contrast to all fields and physical sciences, the vast majority of geoscience degrees are awarded to non-FGCS at *both* the

undergraduate and doctoral level. These data show that in 2016, only 26% of geoscience undergraduates were FGCS, compared to 71% in the physical sciences and 79% in all fields. Also in 2016, at the doctorate level, 22% of geoscience doctorates were FGCS compared to 32% in physical sciences and 36% in all fields (Figure 1b). These data illustrate that FGCS are strikingly underrepresented across all degree levels in the field of geosciences.

Race and ethnicity of first-generation college students

It is important to note that there are many measures of diversity within the FGCS population. Although racial and ethnic demographics data are limited to federally defined categories, we wanted to explore the racial and ethnic background of FGCS vs non-FGCS through time because they provide a basis of comparison with other diversity studies (Bernard & Cooperdock, 2018), which are often used to guide outreach efforts within institutions or organizations.

Figure 2 shows that the majority of undergraduate non-FGCS and FGCS are White; however, there is a larger proportion of White non-FGCS than FGCS (76.5% and 65.3%, respectively). Similarly, undergraduate Asian non-FGCS slightly outnumber Asian FGCS (10.5% to 8.9%). This is not the case for Black, Latinx, and Native American college students. Although these groups account for less than half of undergraduate students in 2016 from both categories, there are over twice as many Black undergraduate FGCS and nearly twice as many Latinx undergraduate FGCS than non-FGCS, while the number of Native American non-FGCS is too low to be included in Figure 2. The same trends are observed at the doctoral level, with slightly different proportions of each group represented (Figure 2b). In all, these data show that the majority of FGCS are White, but the majority of Black, Hispanic/Latinx, and Native American students are FGCS. These statistics are important for FGCS-based diversity and inclusion efforts because it highlights that the FGCS population is racially diverse and therefore FGCS outreach efforts have the potential to impact large proportions of racialized groups along with other students from underprivileged backgrounds.

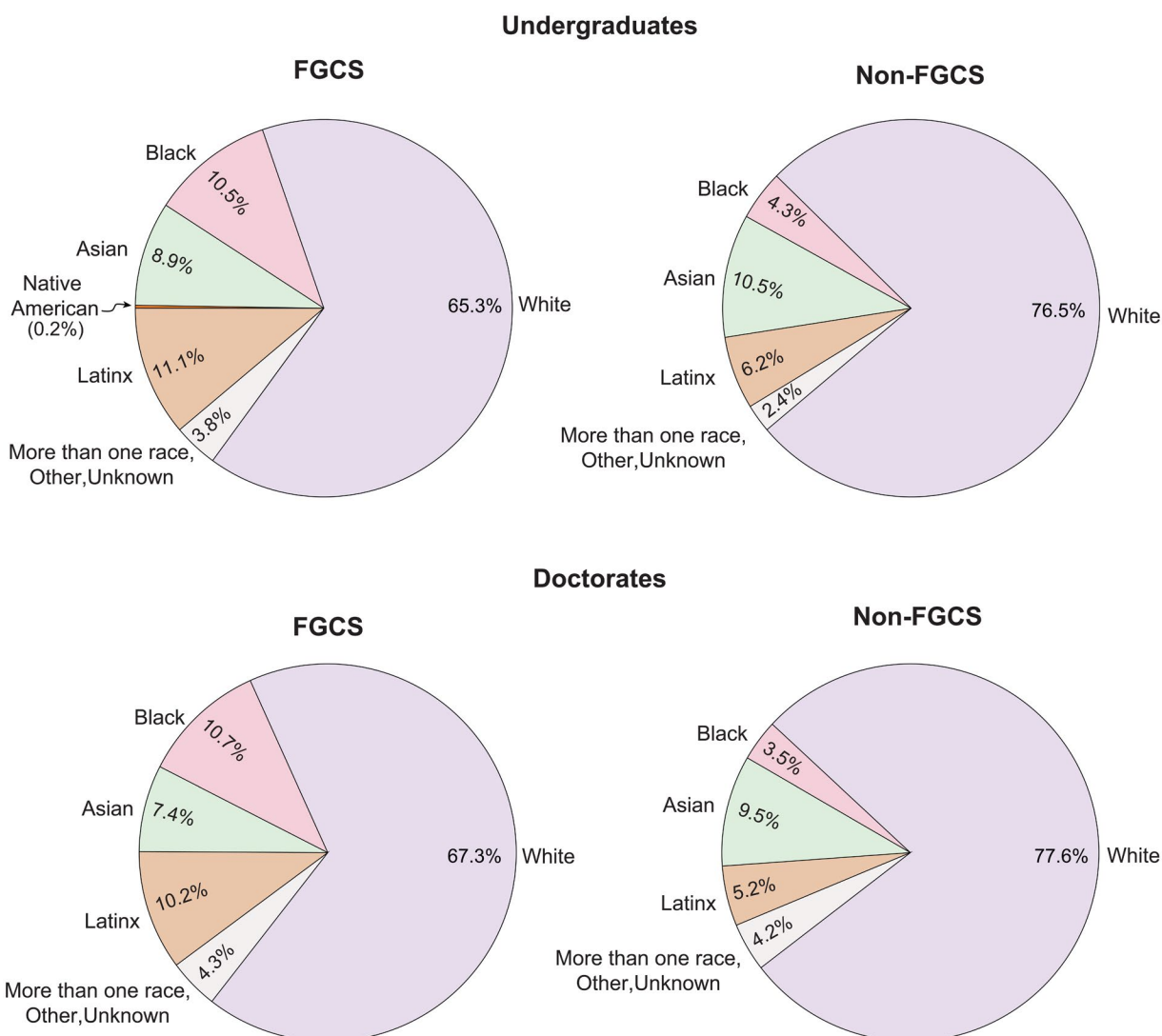


Figure 2. Proportions of undergraduate (a) and doctoral (b) FGCS and non-FGCS by race and ethnicity in 2016.

What institutions and fields are first-generation college students (FGCS) choosing?

Most first-generation college students attend 2-year institutions

If we aim to increase support and recruitment of FGCS to the geosciences, we must know where they are earning their degrees and what they are choosing to study. For many, cost of tuition is a major factor for choosing what institution to attend. In 2020-2021, the average annual tuition cost for public and private 4-year colleges was \$9,377 and \$32,825, respectively. Meanwhile, the average cost for public and private 2-year colleges was \$3,501 and \$15,474, respectively (National Center for Education Statistics, 2022). We found that in 2016 2-year public institutions have a higher proportion of FGCS than 4-year public institutions (70% vs 52%, respectively; Supplement Figure 2), which is in agreement with past studies that show that a majority of FGCS start their college education at 2-year colleges (Chapa, 2006). Private 2-year institutions have comparable proportions of FGCS as public 2-year institutions (68%);

meanwhile, private 4-year institutions are the only type of institution that has a greater proportion of non-FGCS (54%) than FGCS (Supplements Figure 2). For-profit institutions had the largest proportion of FGCS at 2-year and 4-year institutions (77% and 78%, respectively; Supplement Figure 2).

First-generation college students are not choosing the geosciences

For the year 2016, we found that at the undergraduate level in all fields combined, 62% of students were FGCS and at the doctoral level in all fields combined the proportion of FGCS was 38% (Figure 1, Supplement Figure 3). We then looked at the proportion of FGCS in education, engineering, physical sciences, and geosciences. We found that at the undergraduate level, education, engineering, and the physical sciences all had a majority of FGCS (66%, 58%, and 54%), meanwhile, the proportion of undergraduate FGCS in the geosciences was 26%. At the doctoral level, education was the only field that had a majority FGCS (53%), which is

significantly higher than the percentage of doctoral FGCS in all fields (38%; [Supplement Figure 3](#)). In engineering, the proportion of doctoral FGCS was 40%, slightly higher than the proportion in all fields. In the physical sciences, the proportion of doctoral FGCS was 34%, slightly lower than the proportion in all fields. In the geosciences, the proportion of doctoral FGCS was 22%, much lower than in all fields.

Why are first-generation college students (FGCS) so underrepresented in the geosciences?

We want to understand why strikingly few FGCS are choosing the geosciences as a field of study. Here we argue that some of the major challenges for recruitment and retention of FGCS to the geosciences are financial barriers, lack of exposure to the field at 2-year colleges, perceptions of the discipline, and its culture.

Geoscience degrees can be a financial burden

The term “first-generation” college student was created in the 1980s as a way to identify and support disadvantaged students from low-income/underprivileged backgrounds without referring to race and gender (Sharpe, 2017). For many years, researchers investigating FGCS have also used the term “FGLI”, meaning first-generation and/or low income (Ishiyama, 2007; Means & Pyne, 2017; Schademan & Thompson, 2016). Considering that household income increases with education (United States Bureau of Labor Statistics, 2022a), first-generation status and lower socio-economic status are often inextricably linked.

Prior work documents that FGCS are more concerned about money and expect to maintain employment throughout their college career at higher rates than non-FGCS (Pratt et al., 2019). Students who felt the need to work during their first year of college dropped out at higher rates, and the number of hours students expected to work negatively correlated to second-year retention (Pratt et al., 2019). Our data analysis supported these findings. For example, during 2016, one in three FGCS came from households earning \$20,000 per year or less, meanwhile, over 40% of non-FGCS came from households earning \$100,000 per year or more ([Supplement Figure 4](#)). Additionally, we found that 35% of FGCS reported working over 40 hours per week as compared to 27% of non-FGCS. We also found that only 17% of FGCS reported working between 1 and 15 hours per week as compared to 26% of non-FGCS, demonstrating that FGCS tend to work more hours per week than non-FGCS ([Supplement Figure 5](#)). As shown by Pratt and others (2017), this is a major disadvantage for FGCS that negatively impacts their ability to succeed academically and socially. FGCS having more work responsibilities does not just mean less time to work on assignments and study for tests, but it also likely contributes to lower levels of involvement in extracurricular activities, athletic participation, volunteer work, and non-course-related interactions with peers that often predict college success (Pascarella et al., 2004). It is thus not

surprising that various studies show that FGCS experience lower levels of social belonging to the college lifestyle, which is linked to lower retention rates (Ishiyama, 2007; Means & Pyne, 2017; Pratt et al., 2019; Schademan & Thompson, 2016).

These disadvantages stemming from financial insecurity are heightened in the geosciences because, unlike other fields, geoscience classes require additional time outside of scheduled classes and expenses beyond the already costly tuition. Field trip requirements may present a significant challenge particularly for FGCS since many are on the weekend or require extended class time which requires time away from work and/or family obligations. Additional costs include buying or renting field gear, expensive required capstone courses (e.g., field camp), money lost due to taking time off from work, and childcare expenses. Many universities still require field camp courses for degree completion, which often cost between \$1,550 and \$8,954 (AGI, 2017) and are typically 4-6 weeks long. Even if students can receive scholarships that cover the cost of field camp, taking a month or more off from work or family care obligations is simply not feasible for many who are already struggling financially.

Lack of geoscience exposure at 2-year colleges

The student populations of 2-year colleges are often more demographically diverse than of 4-year universities as women, minoritized students, FGCS, and students from lower socioeconomic status are more likely to use 2-year colleges as their access point to higher education due to their open access admission policies and lower tuition costs (Handel, 2013; Pascarella et al., 2003; Terenzini et al., 1996; Wolfe, 2018). As noted above, public 2-year institutions annual tuition costs on average ~\$3,500, whereas 4-year colleges can cost anywhere from ~\$9,000 to over \$32,000 a year. Many FGCS come from households where tuition at 4-year institutions is prohibitively expensive without substantial, often competitive, financial aid packages.

FGCS may prefer starting or completing their college education at 2-year colleges because they are more conveniently accessible across the U.S. than 4-year institutions. FGCS who are more commonly older and have children may have significant roots through a spouse's job or family support with childcare and may not want to move across the state or country to pursue higher education. Additionally, FGCS may prefer to stay closer to family if that is culturally expected of them, as was the experience of one of the authors, or because their family is an important emotional and social support system. Overall, 2-year colleges often offer qualities in higher education that underserved students seek such as affordability, commutability, and more diversity in the student population.

Additionally, FGCS who may want to attend a 4-year university but rely on high school counselors for advice may be misguided or discouraged from applying to 4-year universities. From the experience of two of the authors, counselors in low-income high schools strongly encourage students to attend community college and are only prepared

to advise students through the high school to community college transition. Information on the requirements to apply to elite universities, such as SAT or ACT placement tests, or the fact that elite universities often offer the best need-based financial aid packages was not shared with students.

Regardless, due to a combination of factors, FGCS often start their higher education at 2-year colleges and the geosciences lag far behind the other sciences in bachelors and graduate degree completion rates of students transferring from 2-year colleges (Wilson, 2014; Wolfe, 2018). The geosciences are often referred to as a “found major,” meaning most undergraduate students do not start off as geoscience majors, but discover it as they take general education courses. By the time students transfer to 4-year institutions (if they transfer into 4-year institutions), they have likely already chosen a major or have taken the maximum number of general education courses, leaving little room for exploration or chances to discovering the geosciences. Also, as is the case at the high school level, not all community colleges offer geoscience courses, unlike biology and chemistry, which are much more ubiquitous.

Geosciences is perceived as a less altruistic and marketable major

Another major challenge for recruiting and retaining FGCS to the geosciences are perceptions of the discipline. A study by Sherman-Morris and McNeal (2016) surveyed undergraduate students to understand perceptions of the geosciences. Although it may be surprising to geoscientists, the geosciences were rated lower on ‘helping the environment and helping society’ than biology, chemistry, and engineering. The geosciences were also rated lower on ‘easy to find a job and make a lot of money’ than physics, chemistry, biology, and engineering. There is a clear misconception of the potential for the geosciences to help the environment and society despite the fact that geoscience departments produce graduates who work at the front lines of issues such as energy, mineral resources, climate change, water resources, hazard mitigation, and environmental protection (Sexton et al., 2014). This signals that the general public is not aware of what the geosciences entails, which may stem from a lack of exposure in K-12 curriculum where geoscience content is often not required or is taught as a remedial science. It may also have this reputation because when researching or discussing the type of careers you can pursue with a geoscience degree, oil and mining tend to be the first careers mentioned, which are often perceived as fields detrimental to the environment.

There is also the inaccurate perception that it is difficult to find a job and make money with a geoscience degree. The American Geoscience Institute (AGI) predicts a shortage of geoscientists since a large portion of the workforce will reach retirement age soon (Sherman-Morris & McNeal, 2016; Stokes et al., 2015) and the annual mean wage of a geoscientist is \$83,680 (United States Bureau of Labor Statistics, 2022b). These perceptions and misconceptions present a

particular challenge for recruiting students from marginalized backgrounds since these students responded more positively to ‘helping other people’, ‘helping the environment’, ‘having prestige’, and ‘making a lot of money’ as important factors when choosing a career than more privileged students (Sherman-Morris & McNeal, 2016). These findings are consistent with our observations that FGCS are well represented in education, an altruistic field, at the undergraduate and doctoral level (Supplement Figure 3). Out of the STEM fields, engineering, which is often viewed as a high earning potential field, has the highest percentage of FGCS at the undergraduate and doctoral level. Any number of these factors can contribute to the perception that the geosciences are less altruistic and/or have less career opportunities, making it an unappealing major to FGCS.

Narrow portrayal of geoscience culture

Several studies have investigated the factors that play a role in a student’s selection of a geoscience major (Holmes & O’Connell, 2003; Levine et al., 2007) and while most factors are beyond the reach of a geoscience department, one factor that geoscience departments can control is the information communicated about the field of study and departmental culture in the department website (Sexton et al., 2014). With the understanding that academic departments can be thought of as organizations and their websites serve as a representation of their culture, Sexton et al. (2014) analyzed various geoscience department websites to investigate the characteristics and culture of the departments as interpreted from their website photos. They found that over 80% of all photographs depict outdoor settings, most commonly of a generic landscape or geological feature and without people. Such images do not inform students of all that a geoscience degree can entail and pictures of geologic features such as faults and folds often mean little or nothing to students without the geologic background. Additionally, FGCS are often pressured to major in fields that their family and/or society deems prestigious. Anecdotally, the relevance of geoscience, especially research that relies heavily on field work, is often poorly understood, which could lead to FGCS perceiving it as less prestigious and/or finding it difficult to justify to their family why they would choose that major. Sexton et al. (2014) also found that when people were present in photos on websites, 60% were male and 90% were White. On webpages that depicted field work, there were no non-White instructors or staff portrayed in the photos. Considering that most Black, Latinx, and Native American students are FGCS and 60% of FGCS are women, it is important to think about the ways that visual representations of the geosciences and geoscientists might reinforce an exclusionary culture for people from minoritized identities.

Intersecting marginalized identities compound barriers

The intersection of marginalized racial or gender identities likely further compounds this socio-economic effect. For example, there is a prevalent lack of representation of

racialized groups in outdoor activities in the media (Martin, 2004; McRoberts, 2020) and marginalized groups experience disproportionate danger in the outdoors (Anadu et al., 2020). Also, although international travel may attract some groups to the geosciences, it may discourage undocumented students, students who do not have and cannot afford a passport, and students with passports that do not grant them broad access.

Stokes et al. (2015) collected anecdotal statements from undergraduate students and found that the geoscience culture significantly impacts students who identify as men and women differently (note their data are limited to a binary gender system). Here is a statement by a male student; “You have a different breed of people in the Geosciences. They’re very intelligent and capable of doing important research, but they can still have a beer on the weekend and play in the dirt” (Stokes et al., 2015). Meanwhile, statements made by some women reveal a lower sense of belonging within the geoscience culture; “There’s a stigma to being a girl in Geoscience. Women in geology are thought of as these hippie type ladies, very natural, and sometimes I feel like people expect you to not try to be attractive and not to shave your legs. I dressed up for something once and someone told me that I didn’t look like a geologist. That was weird.” (Stokes et al., 2015). The outdoorsy, “play in the dirt”, masculine culture serves as a gatekeeping tool for many women but may be even more powerful for gatekeeping women from certain cultural backgrounds. For example, Latinas may be particularly impacted since “Hispanics appear to adhere to the most traditional gender-role attitudes and behaviors” when compared to all other racial groups (Roehling et al., 2005). FGCS Latinas may experience a lower sense of belonging in the college culture, as is common among first-generation students, which is further compounded by their race, especially at predominantly White institutions.

Furthermore, being at odds with the outdoorsy, “boys club” culture of the geosciences may further compound the feelings of alienation. This can partially explain why, as of 2016, records show that only 241 doctoral degrees have been awarded to Latinas (Bernard & Cooperdock, 2018). This is only one of many examples of the way FGCS status can compound with other marginalized identities and further emphasizes the need to think about challenges in recruiting and retaining FGCS to the geosciences through an intersectional lens.

Recommendations

A summary of the recommendations can be found in Table 1.

For faculty, instructors, and staff

Studies investigating the factors that contribute to college students’ sense of belonging (Freeman et al., 2007; Hausmann et al., 2007; Means & Pyne, 2017) (corroborated by the authors’ personal experiences) show that relationships with faculty members are particularly important and note that faculty members’ friendliness, helpfulness, and the ability to encourage participation in class contributed greatly to students’ sense of belonging (Freeman et al., 2007). Considering that FGCS often live and work off campus and tend to work more hours, the only time they spend on campus interacting with faculty and their peers may be in the classroom (Engle & Tinto, 2008; Schademan & Thompson, 2016). However, FGCS, especially those from racialized groups, often describe themselves as unprepared for the alienation they feel upon entering college and are more likely to view the campus environment, particularly

Table 1. Recommendations to reduce systemic barriers experienced by FGCS.

Group	Recommendations
Faculty, Staff, and Instructors	<ul style="list-style-type: none"> • Be aware of your position of power and influence and use it to create a welcoming environment to FGCS • Reach out to students regularly and build open-door relationships with them to instill a sense of belonging • Design class requirements to not require significant outside class time assignments • Provide resources and strategies for students to receive needed guidance and support (academic and financial) • Provide students with paid research opportunities
Geoscience Departments	<ul style="list-style-type: none"> • Conduct a self-study to evaluate whether their websites portray the department or discipline as exclusionary • Create outreach materials that can help engage whole families who may not be aware of geoscience careers and opportunities • Design and teach inclusive field safety and skills before every field course • Purchase field gear students can borrow to relieve financial burden on students • Commit department funds to paid research opportunities or internal scholarships to limit the need to work off campus • Conduct student surveys to gauge sense of belonging and commit to addressing issues that arise
Institutions, Funding Agencies, Geoscience Organizations	<ul style="list-style-type: none"> • Implement comprehensive support programs for low-income, FGCS such as opportunities for cohort-based academic and social support • Support and train faculty to be culturally competent and aware of the challenges faced by low-income, FGCS • At 4-year institutions: build meaningful partnerships and recruit from 2-year institutions • Increase funding to 2-year colleges so that instructors can provide meaningful research and field-based experiences • Create clear reporting for abuse and harassment and hold people accountable
First-generation college students	<ul style="list-style-type: none"> • Participate in campus groups and activities that align with your experiences and values to build a sense of community • Apply for scholarships and grants throughout your time in college to help offset cost-of-living expenses • Participate in paid or for-credit research opportunities to build your experience and self-esteem as a scientist • Build faculty relationships to gain insight into different mentoring styles and for future reference letters • Attend conferences to become inspired, find community, and network for future career opportunities

the faculty, as less supportive and less concerned about them (Pike & Kuh, 2005; Schademan & Thompson, 2016).

A recommendation to faculty is to have keen awareness of the particular position of influence they are in and the power they have to enact cultural change within the classroom. We also recommend faculty to internalize the awareness that not all undergraduate students have had the same educational opportunities before arriving at college. Schademan and Thompson (2016) found that instructors who served as cultural agents had nuanced views of college readiness and enacted relational pedagogy in their classrooms. Means and Pyne (2017) found that faculty who reached out to students first and regularly and opened the door to mentoring connections made academic engagement easier for students. They suggested that faculty provide functional strategies for building better relationships with students, demonstrate academic care for student progress, and learn how to support hidden or unexpected learning needs (Means & Pyne, 2017). There is ample geoscience-specific research and resources intended for faculty, instructors, and staff to use to make sure their teaching and mentoring techniques are effective and inclusive. One example is the GEO REU handbook (Sloan & Haacker, 2020) which compiles guidelines created by a wide array of authors and covers topics such as creating engaging and inclusive recruitment materials, developing an anti-racist program, mentoring models, bystander intervention training, inclusivity and respect, sexual harassment prevention, field safety, and more.

Additionally, faculty should not assume or take for granted that what might seem like common knowledge to them is in fact part of the *hidden curriculum*. The hidden curriculum can be a particular disadvantage for FGCS applying to graduate programs, which is often a more complicated process that varies by field and even institution. Some ways that faculty and staff can help demystify this area of the hidden curriculum is by hosting annual information sessions on how to apply to graduate school, research positions, or jobs. Faculty can also provide information on how to apply to their specific program and clearly outline their expectations on their websites. We also recommend that faculty who are mentoring undergraduate students offer time to meet with students to talk about non-research, professional development topics and the graduate school application process. This is also applicable for faculty mentoring graduate students since there is more to thriving in a graduate program and preparing for the next career stage than doing research and completing a dissertation. Cooke et al. (2021) suggest that many advisors might not have open discussions with their advisees on topics such as the impact of imposter syndrome, authorship expectations, time management, funding plans, conflict management, the norms of the department or institution, mentoring needs and implicit bias. These authors suggest that discussing such topics in first-year graduate courses can help better equip students from all backgrounds to successfully navigate graduate school.

We also want to remind senior faculty that the financial burden of earning a college education has changed significantly since they were undergraduates. Tuition cost has

significantly increased, and as shown, FGCS tend to work more hours and therefore have an unequal amount of time outside of class to work on homework, labs, or attend field trips. For geoscience faculty specifically, we recommend that when students must miss class requirements that are outside regular class hours (e.g., field trips, lab experiments) due to work or family obligations, faculty should not reprimand students or assume that they are missing out due to laziness or lack of interest in the class or their geoscience degree. Students who do not complete assignments that require extensive time outside of class for legitimate reasons are often met with disdain and outdated, tedious, and unhelpful make-up assignments (from some of the authors' personal experience). We recommend providing meaningful alternative assignments that apply the concepts, skills, and knowledge that they would have otherwise gained from the planned assignment. We recognize that there are concepts and skills that are best learned hands-on in the lab or the field, however, there are now numerous, readily available resources and technology to create high quality alternative assignments. Although we acknowledge that providing such assignments takes extra time, this can be what is required if we want to diversify the geosciences. We also want to make clear that we are not recommending ending field trips since we recognize the tremendous value and impact that field experiences have on many students and field work is a vital part of geoscience research. However, we do recommend more compassion and flexibility for students who cannot attend field trips due to work, family obligations, or disabilities. We also recommend not equating people's potential to becoming prominent geoscientists to their physical abilities and interest in field work since there are many geoscientists conducting cutting-edge research who primarily do computational or lab-based research.

Finally, we recommend that faculty provide paid research or mentoring opportunities that prioritize FGCS. Since first-generation status is not a visible identity but requires self-identifying and reporting, we recommend that when faculty advertise research and mentoring opportunities, they verbally express their interest in recruiting FGCS for those opportunities and provide a clear and consistent definition of "first-generation" to avoid confusion.

For geoscience departments

Considering that geoscience department websites are outward-facing products and serve as the visible, public representation of the department and discipline, Sexton et al. (2014) recommend that geoscience departments conduct a self-study to evaluate their websites and examine the potential messages their websites' photographs portray about their department and the discipline. They also suggest that deliberate design of the website and broader representation of the people and the activities portrayed might help departments create an online culture that is more welcoming to a range of people. We agree with this advice, but emphasize it can only be truly effective if the department culture is in fact welcoming and supportive to a range of people.

We also want to note that a department's web page does not only serve to attract students, but it can also be a way to convince families to support their children's decision to study geoscience. These websites should highlight the marketable skills that can be earned with a geoscience degree, not just focus on the beautiful landscapes and rugged outdoor experiences. While such imagery should not be completely eliminated, we suggest that geosciences must rebrand and move away from field-focused marketing. Including more pictures of people working in labs, using state of the art instruments and computing, conducting meetings in well-equipped offices, and providing geoscience job statistics, descriptions, and salary information (in multiple languages) may help recruit a more diverse group of students and reduce misconceptions by students and families.

Another way to ease the financial burden and anxieties that FGCS may experience from field trips is for departments to purchase field gear to be loaned to undergraduate students and for the class instructor or staff to incorporate field safety and skills (e.g., how to set up a tent or how to cook in the field) for all students prior to the field trip. We also recommend that departments hold training or workshops with faculty and instructors on how to promote safety while doing field work. We recommend using the "Report of the Workshop to Promote Safety in Field Sciences" (Kelly & Yarincik, 2021) which provides thorough and tangible recommendations.

Another barrier for FGCS working full time while in college is being unable to gain skills through unpaid research or internship opportunities. Committing and advertising departmental funds to paid research, scholarships, or mentoring opportunities that prioritize FGCS would allow them to gain essential skills needed for graduate school or certain jobs. If departments do not have the funding for paid research opportunities, they can allow students to receive upper division credits that count toward geoscience degree attainment through research. This way, FGCS can gain research skills without needing to spend time "after school" and some departments already successfully offer this as an option.

We also recommend that departments survey their students to gauge student satisfaction and sense of belonging to the department through time. Geoscience departments must create space to identify and then devote resources to address the barriers FGCS are experiencing, whether this is financial support, professional development mentoring, or flexibility toward degree attainment.

For institutions, funding agencies, and geoscience organizations

Higher education institutions have the responsibility to investigate and correct their institutional structures that promote exclusion of FGCS and should work to develop solutions that enhance a sense of belonging for students from marginalized backgrounds. Means and Pyne (2017) recommend that colleges and universities should implement more comprehensive support programs for low-income

FGCS such as opportunities for academic and social support. They also recommend that institutions provide support and professional development for faculty to improve the cultural competence and awareness of the challenges faced by many low-income FGCS. Institutions should train and incentivize faculty to use effective pedagogical practices and encourage them to use appropriate forms of academic discourse, facilitate strong peer and teacher relationships, and adapt content to better engage students, helping them to relate course material to their own lives (Schademan & Thompson, 2016). A way for institutions to effectively incentivize faculty is to elevate the importance of teaching and mentoring students from marginalized backgrounds during tenure reviews and recognize faculty who are putting in the work to make a difference.

We also recommend that institutions, organizations, and funding agencies focus recruitment and outreach efforts at 2-year institutions, which have the highest percentage of FGCS and marginalized students (Chapa, 2006). Wolfe (2018) suggests strengthening the pipeline of geoscience students beginning at 2-year colleges and successfully matriculating to 4-year institutions by providing intentional opportunities for student-faculty interactions, raising awareness of careers in the geosciences, and providing students clear information on what resources are available to them and what is expected of them upon arrival at a 4-year university.

Initiatives meant for first-year community college students to "discover" the geosciences before they declare a major may be an effective and efficient way to recruit a more diverse group of students to the geosciences. An example of an initiative that targets first and second year students at 2-year institutions is "PACES", an NSF funded collaboration between the University of Southern California Wrigley Institute and two Hispanic Serving Institutions, LA Valley College and Pierce College. The PACES program provides resources and support for first- and second-year community college students who are interested in pursuing STEM majors and careers. Each cohort participates in two years of activities that scaffold onto existing curriculum at these community colleges and a week-long excursion to the Wrigley Marine Science Center on Catalina Island, CA. Efforts like this that bring college-level geoscience outreach to the 2-year colleges (rather than expecting them to come to the 4-year institution) and provide optional, but not essential, extracurricular experiences (like a week-long field experience), could help avoid misinformation or inaccurate perceptions of the field among undergraduate students and help with FGCS recruitment.

Another example of an initiative aimed at recruiting and supporting 2-year college students in the geosciences as an effort to increase participation from marginalized students is the NSF funded program "Pathways into Geosciences at the University of Arizona." This program focused on providing undergraduate students from Pima Community College and other Arizona community colleges with mentoring, professional development, and paid internship with Arizona-based geoscience companies, agencies or non-governmental organizations. The transfer students

participated in workshops on professional skills in their first year at the University of Arizona such as “Success Strategies in STEM” and “Research Readiness.” The purpose of these workshops and their coursework was to provide transfer students with academic and practical preparation for paid internships with local businesses in the mining industry, hydrologic and environmental consulting, federal, state and local agencies and with environmental nonprofit organizations.

More broadly, we recommend that funding agencies increase support to geoscience programs in 2-year colleges so that instructors have the resources to implement engaging geoscience activities and local field trips. For geoscience organizations, we recommend increasing mentoring and scholarship opportunities for local, national, and international conferences for FGCS at 2-year colleges and for transfer students. Also, since FGCS are often nontraditional students, meaning older and more likely to have children, we recommend making field trips and conferences more child friendly.

Recruitment without retainment is pointless and harmful to those who enter programs only to find hostility, discrimination, and lack of support. Institutions could help address the discriminatory and predatory culture within academia and increase retainment of students from first-generation and other marginalized backgrounds by taking microaggressions and harassment seriously. Institutions should provide clear and digestible information to advisors, faculty, and students about the options and the process for reporting these incidents. To begin detoxifying academic culture, institutions have the responsibility to investigate accusations seriously and always protect victims, not simply side with perpetrators out of convenience or because of their seniority, status, or influence.

To the geoscience community

We should all work toward changing the geosciences culture to be more welcoming to different identities, whether that is gender, sexual orientation, race or ethnicity, religion, age, disability, or a combination of those. We should accept and celebrate our differences and not isolate individuals who do not look, sound, or dress like a “typical geoscientist.” We can shift the culture by refusing to accept archaic and toxic cultural norms, advocating for ourselves and others, and bringing our authentic, human element to our work.

With a rapidly changing world, the geosciences will need to keep up with increasing demand for geoscientists and cannot afford to ignore the large and diverse potential of the FGCS workforce. FGCS is a group that should be targeted when discussing ways to make academia more diverse and equitable. FGCS are extremely underrepresented in the geosciences and, as the least diverse field in STEM, the geosciences have a particular responsibility for evolving into a field that welcomes, recruits, and retains FGCS. As geoscientists, regardless of our status, we each have the responsibility to use whatever power or influence we have to pivot the geosciences toward a more diverse, equitable, and inclusive future.

A personal note to first-generation undergraduates from first-generation PhD candidates

From one FGCS to another, below we outline a few specific strategies that helped us on our journey to our PhD programs that we hope can help future geoscientists navigate academia. We believe that these lessons can apply to all career levels and directions but we focus the discussion on how FGCS can prepare for and navigate the undergraduate to graduate school transition. We want to emphasize that seeking out relationships with faculty in our departments, paid research experiences, scholarships, and grants allowed us to support ourselves financially while staying close to campus. It also helped us develop a research compass, combat imposter syndrome, identify potential mentors, and feel more connected to the college campus.

Two of the biggest barriers that FGCS experience are financial concerns and a sense of belonging to the college campus. We recommend overcoming these by maximizing your time on campus by finding community, funding, and/or paid on-campus work. Finding funding opportunities through scholarships and grants can allow you to minimize the amount of time you need to work off-campus to support yourself (and your family). Finding out what clubs are on campus, paid work opportunities, or scholarships and grants for cost-of-living expenses is often as simple as reading emails sent by your department, academic advisor, or geoscience organizations. For many college students this is the first time they are receiving so many emails and it can feel overwhelming, but a lot of amazing opportunities are hidden in them. Always be on the lookout for funding opportunities and continue to apply to scholarships and grants once you arrive at college if you are still experiencing financial need. Most universities and colleges have a myriad of opportunities that are designed to support FGCS or other marginalized groups throughout their undergraduate career. Scholarships and small grants can provide the financial assistance you need to support yourself while pursuing your degree and can alleviate the need to spend many hours at an outside job that is not building toward your career goals.

We understand that the cultural shock when entering affluent and/or predominantly White institutions can be overwhelming and may make some students want to spend as little time as possible on campus. However, one of the best ways to overcome imposter syndrome and increase your sense of belonging is to find on-campus clubs, organizations, and affinity groups that align with your values. These groups will help you realize that you are not alone and that there are more students out there experiencing these challenges and who are passionate about building community and support systems.

We advise FGCS to seek one-on-one interactions with geoscience faculty as early as possible. Even if you are not struggling with the class content, office hours are a great opportunity to meet faculty on a more personal level. Although intimidating, asking faculty about their academic journey and their research can open a more personal line of communication with them. Talking to faculty will allow you to investigate if their research area interests you and if they

seem like good potential mentors. Finding official and unofficial mentors that you can build genuine relationships with is important because they are often the ones aware of research, internship, or scholarship opportunities. Additionally, if you are on the faculty's radar, they are more likely to nominate you for awards that are important for your resume/CV and can come with monetary compensation. Finally, one of the most important parts of graduate school applications are letters of recommendation from faculty. If you begin building genuine relationships with faculty early on, your chances of receiving a glowing letter of recommendation will be higher.

We highly recommend finding for-credit or paid research opportunities, which can range from completing a research project to work-study positions. While not required for graduate school applications, research experience is an unspoken expectation and highly esteemed by faculty and admissions committees. Additionally, gaining research experience often helps you feel more connected to your department and/or major, and helps you build confidence in your abilities as a scientist.

Once you have completed research, we recommend attending and presenting your research at national conferences such as the Geological Society of America (GSA) and the American Geophysical Union (AGU). Presenting your research at conferences can help you grow professionally by practicing essential skills such as public speaking and networking. These conferences have recruiting and information booths run by geoscience departments and companies that can serve as an opportunity to meet with potential advisors or explore geoscience career options. Although conferences are costly to attend, faculty and departments often have funds to support you. Organizations like GSA have scholarships for FGCS and racialized students, such as GSA's On To the Future program. If you can attend these conferences, we recommend attending the Diversity, Equity, and Inclusion and Education talks and posters. There you will discover that people all over the country are invested in addressing systemic issues and finding solutions. You may also be more likely to find faculty and mentors who represent you and your interests.

Finally, we recommend seeing your background and struggles not as a disadvantage, but instead feeling empowered by them. Despite all the challenges you may have faced, you made it, you deserve to be here, and you belong. See the ways that you do not fit into the traditional geoscience culture as a strength. Your differences bring to the field something it is severely lacking, diversity. We recommend refusing to fit into the geoscience student mold if it means severing other parts of your identity. Bringing your authentic self will only encourage others to do so. Finally, above all else, prioritize your mental health and well-being. Celebrate your wins (big and small) and be immensely proud of yourself for persevering despite all odds!

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