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A Mixed-Methods Study of Geoscience Identity, Race/Ethnicity, and Gender in Senior Undergraduate Geoscience Majors

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A Mixed-Methods Study of Geoscience Identity, Race/Ethnicity, and Gender in Senior Undergraduate Geoscience Majors

By

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Accepted in Partial Completion

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Master's Thesis

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Willa Lehman Rowan

August 10, 2023

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Abstract

I conducted a mixed methods study of geoscience identity in undergraduate students to examine the cultural and social aspects of geoscience degree programs. White students are overrepresented in geoscience, and a priority of anti-racism efforts in the field is listening to the experiences of students who are Black, Indigenous, or people of color (BIPOC) to better inform equity and inclusion goals. Structural racism in geoscience pushes BIPOC students out of the field, and it can be better understood by studying socially constructed aspects of learning such as geoscience identity. This study is the first to measure geoscience identity with a large enough sample size to determine statistical significance across race and gender demographics. Using a mixed methods approach, I adapted validated survey tools from other STEM fields to create a geoscience identity survey and distributed it to undergraduate geoscience majors at 99 universities. To ascertain the aspects of a geoscience degree program experience that influence students' geoscience identities, the survey also asked students to rate a list of common experiences known to influence geoscience identity and share experiences through open-ended prompts. Results from 139 respondents indicated that, like in other STEM fields, white students identify as geoscientists more than BIPOC students ($p = 0.03$). Despite low response rates from white male students, findings were still significant, with the group showing the strongest geoscience identity of all other groups, primarily in the "performance" and "competence" domains of geoscience identity. This is a departure from other research in STEM that found racial disparities in the "recognition" domain of science identity. Thematic analysis of open-ended survey questions showed that BIPOC students faced more structural barriers and microaggressions than their white peers throughout their completion of a geoscience undergraduate degree. Some students of underrepresented racial/ethnic backgrounds reported feeling like they didn't belong in the field because nobody in their department shared their

identities. This contrasts with white students, who were more likely to have positive, formative experiences and feel a sense of community and belonging in their department or in the field in general. From this study's findings, I make recommendations for geoscience departments committed to anti-racism to improve equity and inclusion in their learning spaces.

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1. Introduction

Identity is a critical tool for understanding how people learn and pursue career paths (Gee and Gee, 2000). A person can have individual identities as well as identities that exist as memberships in certain groups, and they affect how that person experiences their education (Chang et al., 2011; Chemers et al., 2011). Education research within science disciplines has often used science identity, which is a student's ability to identity as a scientist or a "science person", as a tool to understand the social-emotional components of learning in science, technology, engineering, and math (STEM; e.g. Hazari et al., 2013; Bahnson et al., 2021; Kortz et al., 2020; Chen et al., 2021; White et al., 2019). Education research within geoscience is no exception, and a student's ability to identify as a geoscientist has been found to be influenced by a range of experiences from fieldwork (Streule and Craig, 2016) to research opportunities (Cooper et al., 2019). Previous studies document that strength of identity is an indicator of student success and persistence into science careers (e.g. Chemers et al., 2011, Vincent-Ruz and Schunn, 2018), making it a useful tool in understanding how to retain more geoscientists in the field.

Increasing racial and ethnic diversity in the geosciences is a priority, as the field is overrepresented by white students more than in any other field in STEM (NCSES, 2021). Geoscience has awarded the lowest percentage of degrees to students identifying as Black, Indigenous, or People of Color (BIPOC) than any other STEM field (Bernard and Cooperdock, 2018; Huntoon and Lane, 2007). The percentage of BIPOC geoscience faculty at research institutions is 13.6% (Nelson, 2017). These numbers have hardly changed since the 1970s despite demographic shifts, with BIPOC populations increasing from 17% in 1970 (Gibson and Jung, 2002) to 35% in 2019 of the total US population (NCSES, 2021). Representation on its

own is also not a true measure of equity and inclusivity in a field, but just an indicator of the overall culture in the field (Dutt, 2019). Geoscience as part of the larger domain of science has often been described as what Carlone and Johnson (2007) succinctly put as "a culture characterized by white, masculine values and behavioral norms, hidden within an ideology of meritocracy". Many geoscientists of color report experiencing departmental cultures that disregard considerations of race, and state that they do not even feel comfortable bringing up race with their white colleagues (Dutt, 2019).

Many programs aiming to attract and retain BIPOC students and geoscientists have been successful on local scales (e.g., Karsten, 2019; Riggs and Alexander, 2007). These programs consist of summer research opportunities (Cooper et al., 2019), mentoring programs (Stokes et al, 2015), "bridge" programs from high school and community college to 4-year programs (Riggs et al., 2018), and more. These efforts show local success in improving outcomes for BIPOC students (e.g. Baber et al., 2010), but by themselves cannot solve the larger structural issues within geoscience culture that are actively excluding BIPOC students and geoscientists from the field (Riggs and Alexander, 2007). Previous studies and commentaries cite discrimination and harassment in the geosciences as a barrier that must be overcome in order to attract and retain BIPOC students once they have been exposed to opportunities in geoscience (Morris, 2021; Dutt, 2019; Marín-Spiotta et al., 2020).

Recent progress in improving diversity has been slow and uneven, and most gains in racial diversity have been concentrated at a few universities, most of them minority-serving institutions (MSIs; Beane et al., 2021). Understanding how common experiences influence geoscience students' identity formation could therefore be useful in informing goals to attract and retain

BIPOC students. No previous studies have covered a large enough sample size to obtain a statistically significant relationship of geoscience identity and race and ethnicity.

Outside of geoscience, studies of science education experiences as they relate to race have revealed tensions between BIPOC students' racial identities and their science identities (Hazari et al., 2013; Chang et al., 2011; Carlone and Johnson, 2007). From K-12 (Ruz and Schunn, 2018) through professional careers (Carlone and Johnson, 2007), BIPOC members of STEM disciplines report less strong science identities as compared to their white counterparts. Science identity and gender also correlate, with women and non-binary students in STEM identifying less as scientists than their male counterparts (Williams and George, 2014; Hazari et al., 2010).

I performed a similar investigation for geoscience programs by surveying undergraduate geoscience majors at multiple universities on the strength of their geoscience identities. To fulfill the goal of better understanding the aspects of geoscience programs that encourage or discourage BIPOC students from persisting in the field, I also gathered information on how common experiences in a degree program, such as field trips or learning about careers, affected students' geoscience identities. This provided context to potential disparities in geoscience identity between white and BIPOC students.

This research aims to contextualize the demographic disparities in geoscience by analyzing the social and cultural aspects of geoscience programs that privilege those closest to the white male norm. Articles reporting on low diversity statistics in geoscience as an indicator of equity and inclusion note that analyses of social factors as they relate to students' identities are needed in the field (Ali et al., 2021; St. John (Ed), 2018). Because geoscience identity is both socially constructed and a known indicator of persistence in the field, it is an ideal framework for addressing this research need.

Positionality Statement

I approach this work knowing that my position as a cis-gendered, white woman gives me a particular lens through which I view this study (and the world), and that lens ultimately influences this project. I also entered geoscience with specific knowledge of the field from growing up with a geologist father. Although this makes me well-disposed to understand and have fluency in the dominant geoscience social norms that this study explores, I must rely completely on the accounts of BIPOC geoscientists to understand how the culture in geoscience is tokenizing or exclusionary to members of systemically non-dominant (Jenkins, 2017) racial and ethnic groups. Literature on race and science identity as well as commentaries of racism in the geosciences by BIPOC geoscientists heavily influenced the creation of this study's survey tool. I used data interpretation techniques designed to minimize bias to limit the effect of my positionality on the outcome of this study but recognize that not all biases can be eliminated.

2. Background

I chose senior (4th year or later) undergraduate geoscience majors in the U.S. as the study population. Undergraduates majoring in the geosciences will have had exposure to all basic elements of the field by the time they graduate. By this point in their education, most students know if they plan to pursue careers in the geosciences, continue into graduate education or pursue a different path after graduation. A bachelor's degree is the highest level of education in the geosciences that many students attain and is the minimum requirement for many positions in the profession. An excellent time to capture the undergraduate geoscience experience as it pertains to identity development, then, is to survey students right before they graduate.

2.1 BIPOC Geoscientists and Representation

This study compares the relationship between geoscience identity in BIPOC students to that of white students. I rely heavily on the terminology and scope used by Graham et al. (2022), who studied factors impacting the recruitment and retention of BIPOC marine scientists (who fall under the umbrella of geoscientists). This comparison between BIPOC and white scientists is made because the aspects of geoscience programs that influence geoscience identity formation reflect larger societal structures that have made white people systemically dominant and BIPOC people systemically non-dominant (Jenkins, 2017). Many (and by some methods of categorization, all) BIPOC students belong to racial or ethnic group(s) that are awarded a lower percentage of geoscience degrees than their overall proportion in the general population. This includes the ethnic category of Hispanic or Latino, and the following racial categories: American Indian or Alaska Native, Asian, Black or African American, and Native Hawaiian or Other Pacific Islander (NCSES, 2021).

The National Science Foundation (NSF) surveys and publishes demographic and degree data through the Women, Minorities, and Persons with Disabilities in Science and Engineering reports (Table 1; NCSES, 2021). NSF defines "underrepresented minorities (URM)" in STEM as all of the above mentioned minoritized ethnic and racial categories, minus the Asian group (NCSES, 2021). Due to the legacy of the formerly overlapping categories of "Asian", "Asian and Pacific Islander", and "Native Hawaiian and Other Pacific Islander" in NSF surveys, it is difficult to determine which currently used demographic groups are truly underrepresented in the geosciences. Because this study is concerned with culture, norms, and power dynamics in geoscience programs as much as representation, I will focus on all systemically non-dominant

racial and ethnic categories under the umbrella term, BIPOC (Jenkins, 2017; Graham et al., 2022).

2.2 Social-Emotional Learning

Beyond solving the issue of representation, geoscientists have begun examining more subjective phenomena like social norms and culture in the geosciences, which is essential to fully realize the accessibility and inclusion goals of the field (Riggs et al., 2018). Anti-racism action plans have called on geoscience departments to gather information on the experiences that BIPOC students have had in their degree programs to increase understanding of the social and interpersonal aspects of the field (Ali, 2021). More recent initiatives to attract and retain BIPOC students in geoscience programs have focused on social-emotional factors of learning such as geoscience identity (being able to identify as a geoscientist) or self-efficacy (confidence in one's ability to succeed; e.g. Baber et al., 2010). Social-emotional factors of learning strongly impact student success and persistence in geoscience, leading to desired outcomes such as completing degree programs and entering the geoscience workforce (Kortz et al., 2020).

2.3 Intersectionality

As students with multiple minoritized identities often feel compounding effects of discrimination based on gender, race, ethnicity, and other backgrounds (Carlone and Johnson, 2007), this study will also add dimensions to an already large body of research on gender as it relates to geoscience identity (Marin-Spiotta et al., 2020; Perin et al., 2020). Intersectionality, a framework created by Dr. Kimberlé Crenshaw to address the synergistic inequities faced by Black women (Crenshaw, 1991), provides an accurate and holistic approach to capture students' entire lived experience (Nuñez et al., 2019). Although this study will only collect gender identity

and race/ethnicity demographics from respondents, it can add context to geoscience's lack of racial and ethnic diversity and recognize areas where geoscience programs can improve experiences afforded to BIPOC students. Responses from female and non-binary students who are members of minoritized race/ethnicity groups speak to the compounding effects of oppression in a cis-white-heteropatriarchal-dominated field (Carlone and Johnson, 2007).

Geoscience degree programs are systemically inequitable with regards to other aspects of students' identities as well, such as socio-economic status, sexual orientation, or disability status (Atchison and Libarkin, 2013; Perera et al., 2021). It is possible – likely, even – that geoscience identity varies across these demographics as well, but quantifying these relationships is beyond the scope of this study. The geoscience identity survey that I have developed for this study may be used again to compare other elements of one's geoscience identity that extend to these other demographics.

3. Problem Statement

To examine the complex factors surrounding geoscience identity and race/ethnicity in geoscience students, my research questions are as follows:

1) Does the strength of undergraduate geoscience students' geoscience identity (the extent to which a student can identify with being a geoscientist) differ based on students' race or ethnicity?

2) Which experiences in an undergraduate geology program impact a student's geoscience identity formation?

Both of these questions are explored in the geoscience identity survey, so the research tool consists of a single survey deployed to undergraduate geoscience majors in the spring of their senior year. Although this study focused on the racialized experiences of geoscience majors, I also gathered information on survey respondents' gender identities to examine the intersections of race and gender with regard to students' geoscience identity formation.

4. Methods

This project consisted of three major stages: survey creation and piloting, survey administration, and data analysis and interpretation.

4.1 Mixed Methods Research

This project benefits from a mixed methods design, where the combination of quantitative and qualitative findings provides a synergistic effect, or analytic texture (Miles et al., 2020), to the findings of the study. The survey tool has Likert-type scale questions whose responses were used in statistical analysis. The survey also has open-ended question prompts whose responses were evaluated with thematic analysis. Student responses were grouped into a small number of demographic categories for statistical analyses, but individual students' identities were considered during qualitative analysis to allow for exploration of the nuances of individuals' experiences. Qualitative and quantitative findings were then merged together and compared for degree of fit (Fetters et al., 2013).

4.2 Theoretical Framework

I adapted the Science Identity theoretical framework of Carlone and Johnson (2007) to create a Geoscience Identity framework. It includes the three components of science identity as they relate to geoscience: competence, which is a person's understanding of geoscience concepts and content; performance, which is a person's social performance of geoscience activities; and recognition, which is recognition by a person's peers, faculty, and family as a geoscientist or "geoscience person". These three components make up a person's geoscience identity, which influences and is influenced by their personal or social identities (Fig. 1).

4.3 Survey Creation

The Geoscience Identity Survey contains four parts. The first part addresses research question #1 with a measure of geoscience identity, which tests the role of the recognition, performance, and competence domains of geoscience identity. The second part addresses research question #2 with evaluations of common experiences known to influence geoscience identity. The third part further addresses research question #2 as well as contextualizes the survey's quantitative data with open-ended questions. The fourth part, which collects demographic information, is critical for the research goals of the study.

I created a measure of geoscience identity by adapting pre-existing, validated surveys based on the science identity theoretical frameworks put forth by Carlone and Johnson (2007) that test strength of identity in other fields in STEM. A wealth of studies have designed and validated survey tools that measure science identity through the three components of recognition, performance, and competence (e.g. Sitong and Wei, 2020; Chen et al., 2021; Godwin et al., 2016). Although many surveys of science identity in high school or first-year college students

consider the additional component of "interest" following the theoretical framework put forth by Hazari et al. (2010), I chose not to include it as interest is assumed to be a given in this project's study population of graduating senior geoscience majors. I adapted a set of questions testing the recognition component from Williams and George (2014) and a composite set of questions testing the components of performance and competence from Godwin et al. (2016). The only changes made to the survey questions were substituting "scientist" with "geoscientist" and "physics" for "geoscience" to make questions appropriate for the survey population (Fig. 2).

The sets of questions were left intact and set to a 5-point Likert-type scale that included the following options: "1 = strongly disagree", "2 = disagree", "3 = neither agree nor disagree", "4 = agree", and "5 = strongly agree" (Appendix A). With the numbering system embedded into the scale, student responses could be converted into numerical scores for statistical analysis.

In order to address this study's second research question and evaluate the experiences in an undergraduate geoscience program that influence students' geoscience identity, I first needed to develop a comprehensive list of all experiences that have the potential to influence identity formation. I conducted a review of literature for all peer-reviewed studies that link common experiences in geoscience programs to identity, persistence in the field, self-efficacy, intent to major, or interest in geoscience careers. I performed keyword searches for "identity", "persistence", "affective factors", "affective learning", "self-efficacy", "retention", "pipeline", "geoscience person", "science person", and several more. I searched academic journals such as the Journal of Geoscience Education, Nature Geoscience, GSA Special Papers, and the Journal of Research in Science Teaching.

The resulting list of experiences (Table 2) was put into a five-point Likert-type matrix in the survey, with the following rating options: "-2 = had a strong negative impact", "-1 = had a

negative impact", "0 = had neither a positive nor a negative impact", "1 = had a positive impact", and "2 = had a strong positive impact". As with the measure of geoscience identity, the numerical ratings of each experience could then be analyzed statistically.

The survey also included five short-answer questions that elicited responses about watershed moments and other impactful experiences in students' geoscience degree journeys. The number of short-answer questions was limited to five to prevent survey fatigue (Porter et al., 2004). Four of the five questions focused on factors of motivation (van der Hoeven Kraft et al., 2011) and educational transitions, as they often involve – or are triggered by – transformative experiences (Stokes et al., 2015; Levine et al., 2007). Two questions addressed students' choosing the major and entry into the department, one question asked if students had ever considered leaving the major, and one question queried students on their plans to enter into geoscience careers after graduating. The final question invited students to share any important aspects of their geoscience degree experiences relating to their geoscience identities that they hadn't already shared (Appendix A). The survey followed a concurrent design, meaning all data (quantitative and qualitative) were gathered from students at the same time (Fetters et al., 2013) and in one sitting. The survey included several prompts asking students to elaborate on any of their answers and open-ended questions inviting students to share anything that had not come up in other questions, as there was no opportunity for follow-up after students submitted their survey responses anonymously.

4.4 Survey Piloting

I piloted the geoscience identity survey tool (Appendix A) with a small sample population, which was the current Master's students at Western Washington University's (WWU) Geology Department (n=18). This pilot was done with a convenience sample to test the survey's

usability and functionality with students who could easily reflect on their undergraduate experiences, many of them recent (within two years), without influencing members of the actual undergraduate survey population. After feedback from graduate students and analyzing survey responses, I made minor changes to the survey to provide definitions for some terms (e.g. microaggressions, macroaggressions) and to improve answering options for multiple choice questions, such as enabling survey respondents to select more than one answer in demographics questions.

4.5 IRB Review

I submitted the geoscience identity survey to WWU's Institutional Review Board (IRB) committee for human subjects review and it was approved with an "exempt" status. Several steps were taken to ensure the anonymity of survey respondents, such as programming the Qualtrics survey not to collect IP addresses and collecting email addresses for the gift card raffle, used to incentivize participation, in a separate survey.

4.6 Data Collection

I sent the survey to 99 universities (Fig. 3), which were chosen from the list of recipients of the American Geosciences Institute Status of Recent Geoscience Graduates (Wilson, 2019), with additional minority-serving institutions (MSIs) added to the list (see Fig. 3). The list of 99 universities represented a cross-section of geographic areas of the US, public and private universities, large and small universities. MSIs were sought out to ensure a large number of BIPOC respondents. The survey was sent to faculty, administrators, or department chairs in geoscience departments with a request to distribute to their undergraduates using language

approved in our IRB application (Appendix B). In order to ensure anonymity, student participants were not asked to report their school on the survey.

4.7 Quantitative Analysis

I conducted statistical analysis on the Likert-type geoscience identity survey responses using base R and the packages tidyverse (Wickham et al., 2019), WRS2 (Mair and Wilcox, 2020), psych (Revelle, 2023), and viridis (Garnier et al., 2023). After importing the survey data from Qualtrics, I cleaned the data by removing unnecessary columns such as timestamps and empty rows resulting from respondents who did not answer any survey questions. I reverse-scored the appropriate questions from the geoscience identity survey (Fig. 2) to maintain consistency with the trend of higher scores and positive responses. I then summed each student's responses to the 15 questions of the geoscience identity tool, which are each set to a numerical scale of 1-5 (Appendix A). The result is a total "score" of geoscience identity for each student. I then grouped student responses into categories of "White" and "BIPOC", and then further into categories "Male" and "Female and Non-binary". Female and non-binary students were grouped together because there were too few non-binary student responses to be able to use separately for statistical analysis. Although these groupings of racial/ethnic and gender identities enable statistical comparison between systemically dominant and non-dominant groups, they are problematic in lumping together survey responses of students who may have identities that are very different from one another.

I checked the datasets for normality and homogeneity of variances. Because the data showed non-normal distributions through visual checks (Fig. 4; Fig. 5) and a Kolmogorov-Smirnoff test ($p<0.001$), heteroscedasticity through a Levene's Test ($p=0.05$), and had somewhat unequal sample sizes (Fig. 4), common parametric statistical tests to compare groups were not

appropriate on their own. I used bootstrapping as a robust method of analysis that would allow for statistical comparisons among these groups. Following the methodology put forth by Mair and Wilcox (2020), I used a bootstrapped t-test to compare the mean identity scores of BIPOC and white students. I used a bootstrapped one-way ANOVA to compare the mean identity scores of groups broken down by BIPOC and white race/ethnicity groupings, and male and female & non-binary groupings.

Because the geoscience identity survey tool is composed of validated sets of questions on the "Recognition" component of geoscience identity (Godwin et al., 2016) and on the "Performance/Competence" components of geoscience identity (Williams and George, 2014), it was possible to test for differences within these two distinct sets of questions. I repeated the bootstrapped ANOVA technique on the "Recognition" and "Performance/Competence" sections of geoscience identity. This allowed me to pinpoint specific dimensions of geoscience identity where groups of students may differ.

To evaluate the next section of the survey evaluating common experiences in a geoscience program, I calculated descriptive statistics of the Likert-type scale ratings of the fourteen common experiences known to influence geoscience identity that were generated from literature review. This was done primarily to measure the spread of the ratings of each common experience as positively or negatively impacting students' geoscience identities. For example, "research experiences (non-course based)" had a mean rating of 1.49 (SD=0.68), halfway between the ratings of "1 = had a positive impact" and "2 = had a strong positive impact", and was compared to the ratings of other experiences. To see if the common experiences were rated differently by students of different race and gender demographics, I used the same bootstrapped ANOVA test on each of the fourteen common experiences (Table 2) to compare average ratings

broken down by BIPOC and white race/ethnicity groupings, and male and female & non-binary groupings.

4.8 Qualitative Analysis

I used thematic analysis to extrapolate meaning and patterns from the five short-answer responses in the geoscience identity survey using Atlas.ti Windows (Version 23.1.10). Thematic analysis is a multi-stage, iterative process (Miles et al., 2014 Terry and Hayfield, 2021; Nowell et al., 2017), where text is coded systematically for common concepts and ideas. Codes are then grouped into themes, which capture the overarching patterns of sentiments and experiences of the study group. Although some studies use qualitative findings as a way to corroborate the quantitative findings of a mixed methods study (e.g. White et al., 2018), I interpreted qualitative findings on an equal standing to quantitative results. I then measured the extent to which the qualitative and quantitative results corroborate or contradict each other (Fetters et al., 2013).

Working in a team, Dr. Robyn Dahl and I first familiarized ourselves with the data by reading through the survey responses, taking notes on our impressions, and noting salient or surprising passages (Terry and Hayfield, 2021). Becoming familiar with the survey responses gave us an overall impression of the data and allowed us to calibrate our coding approach. We compared the survey responses to the Geoscience Pipeline framework (Levine et al., 2007), which included a list of "four-year college indicators" of student persistence. We confirmed that topics covered by the survey responses were relevant to the list of indicators from the Geoscience Pipeline, which supported its use as a template in a deductive approach to coding the data (Terry and Hayfield, 2021). Familiarizing ourselves with the data also allowed us to identify emerging prototype themes that could be revisited in later cycles of analysis (Xu and Zammit, 2020).

The next stage of thematic analysis involved generating codes, or labels consisting of words or short phrases, that described the concept or idea of a section of text (Miles et al., 2014). For example, the code "engaging geoscience course content" was generated to describe the quotation "We did a lab with the steam table that I loved". We then developed a code manual (Appendix C) with a combination of deductive and inductive coding (Fereday and Muir-Cochrane, 2006). Twenty-two deductive codes were taken from the Geoscience Pipeline framework (Levine et al., 2007), such as "effective instruction" and "required STEM courses", and thirty-three inductive codes arose from reading a subset of survey questions and creating codes to describe passages that were not already captured in the Geoscience Pipeline framework, such as "interest" and "physical accessibility". We also applied a "positive" or "negative" sentiment to each code based on the context of the survey response. Once we believed we had achieved code "saturation," we read through any remaining survey responses again to ensure all concepts were represented by a code (Miles et al., 2014). The resulting code manual included the list of codes, each code's definition, a description of types of responses to which the code could be applied, and one or two examples from the data fitting each code (Appendix C; Nowell et al., 2017).

In order to test our code manual for reliability and check against distortions or biases, we calculated inter-coder agreement. Inter-coder agreement is a measure of how reliably multiple coders apply the same code to a relevant passage in the data (Krippendorff, 2013). Inter-coder agreement was tested with a qualitative researcher, Dr. Thanh Lê, who was briefed on the code manual and was familiarized with the code system and all code definitions. Dr. Lê and I then separately coded a randomly selected 20% subset of the survey responses. We did not consult each other during the coding and no codes were altered, added, or subtracted from the code manual. I then merged our two coded datasets back into Atlas.ti and calculated a Krippendorff's

alpha coefficient of reliability, which was $\alpha = 0.80$. A Krippendorff's alpha coefficient meeting the standard of $\alpha = 0.80$ indicates the coding system is reliable (Krippendorff, 2013).

After calculating a satisfactory coefficient of inter-coder agreement, Dr. Dahl and I proceeded to code the entire dataset. I then began sorting and grouping codes into prototype themes, which are overarching descriptions of a facet of the dataset. To group codes into prototype themes, I looked at co-occurrences of codes, code frequencies, and the presence of positive or negative sentiments paired with codes (White et al., 2018). I maintained themes as only prototypes at this stage to allow for ongoing construction, deconstruction, and reconstruction of themes as we continually revisited the data (Terry and Hayfield, 2021). Some prototype themes were created as catch-all groups for codes that didn't fit into other themes. Each code was placed into only prototype theme.

In this next phase of thematic analysis, I revisited, reviewed, and further developed the prototype themes. I reread the survey responses to ensure groupings of codes reflected similarities of ideas and sentiments in the data (Xu and Zannit, 2020). I also reviewed whether themes truly captured the full spectrum of the sentiments of the responses coded within them (Terry and Hayfield, 2021). I examined prototype themes that were strongly connected to each other through similar concepts or had co-occurring codes. I either further refined them so that they represented two fully distinct themes, or I combined or redistributed them into one or more themes (White et al., 2018). For example, the prototype themes "outdoor experiences", "geoscience courses", and "geoscience extracurricular activities" included codes that discussed similar concepts and experiences. After further inspection of code co-occurrences and accompanying "positive" and "negative" sentiment codes, I rearranged codes into new themes that described distinct phenomena in students' experiences: "engaging classroom experiences",

"meaningful extracurricular experiences", "issues with course/degree requirements", and "othering in geoscience courses". A total of thirteen themes emerged from the review process.

I then diagrammed the thirteen themes according to their relationships to one another and the data (as discussed further in Section 5.2). Based on fit with the emerging themes, I referenced the theoretical framework of Opportunity Structures (Gray et al., 2018) to aid in diagramming themes. Opportunity Structures is a race-based perspective to the multiple levels of power in a school environment – interpersonal, instructional, and institutional – that can contribute to Black students' sense of belonging (Gray et al., 2018). I also chose the Opportunity Structures framework to minimize my bias as a white researcher, as the framework examines structural domains of power and privilege that are often invisible to those who benefit from it. Diagramming themes as a visual practice served to place them into theoretical relationships and hierarchies (Terry and Hayfield, 2021). In the process of diagramming themes, I further refined themes and the codes assigned to them.

4.9 Content Analysis

Some qualitative findings were able to be summarized quantitatively (Sandelowski, 2000) through a process known as content analysis (Krippendorff, 2013). Quantitative analysis of qualitative data adds an additional dimension of understanding to the qualitative data and can effectively explain similarities and differences between qualitative and quantitative results (O'Cathain et al., 2010). To analyze the coded short-answer responses from a quantitative standpoint, I calculated the frequencies of code and theme occurrences by students' race and gender demographics, including the frequencies of applied positive and negative sentiments. Because the responses to a particular question, "Did you ever consider leaving your geoscience major? If so, why?" yielded particularly rich results, I chose it for additional quantitative

analysis. Answers from students replying that they had considered leaving the major were subsetted, and the codes and themes associated with their answers were analyzed for frequency in the total population and by different demographic groups of students.

4.10 Data Integration

Once I completed statistical analysis of quantitative data and thematic analysis of qualitative data, I used a merging method of data integration to compare and analyze the two datasets (Fetters et al., 2013). This entailed comparing students' geoscience identity scores, their ratings of which experiences positively or negatively impacted their geoscience identities, and the codes associated with their short answer responses. A main goal of merging and comparing quantitative and qualitative results was to evaluate the fit of the two datasets (Fetters et al., 2013), with possible outcomes being confirmation, expansion, or discordance (White et al., 2018). I developed a convergence coding matrix to systematically compare the major findings arising from the quantitative and qualitative datasets (O'Cathain et al., 2010). The matrix (Table 4) has a row for common experiences influencing geoscience identity, and columns include the results from quantitative analysis and, if applicable, the findings from qualitative analysis. For each factor, I evaluated the degree of fit between quantitative and qualitative findings. Additional comparisons between different sections of survey results were evaluated for fit and described in narrative.

5. Results

After sending the geoscience identity survey to universities in May 2022, I received 168 responses from senior undergraduates majoring in geoscience. 139 of those respondents provided demographic information that allowed their responses to be used in analysis. This allowed for

statistical comparison between BIPOC (n=64) and white (n=75) students, and among BIPOC female and non-binary (n=37), BIPOC male (n=27), white female and non-binary (n=51), and white male (n=24) students. The mean geoscience identity score of all respondents was 58.4, out of a maximum possible score of 75. All of the 139 survey respondents completed the geoscience identity section and the section rating the fourteen common experiences known to influence geoscience identity, and 129 students answered open-ended questions. Descriptive statistics and demographic information for the three survey section results can be found in Table 3.

5.1 Quantitative Results

My first research question is to examine the relationship between geoscience identity and race/ethnicity. To compare the mean geoscience identity scores between BIPOC and white students, I used a bootstrapped t-test with 4999 bootstrap replicates and calculated a p-value of 0.03 (Table 3). This is moderate evidence against the null hypothesis that the two groups do not differ in mean geoscience identity score. I calculated a small-medium effect size with a Cohen's *d* of 0.37. To compare results by race/ethnicity and gender demographics, I used a 20% means trimmed, bootstrapped one-way ANOVA which found $F = 4.9$, $p = 0.008$, meaning the group means were not all equal. The effect size is Cohen's $f = 0.34$. A pairwise post-hoc test showed that white students of any gender had significantly ($p < 0.01$) higher science identity scores than BIPOC male students. All other group pairings were not significantly different from each other (Fig. 6a).

I performed means-trimmed, bootstrapped t-tests and ANOVAs on the "recognition" component of the geoscience identity scores and found no significant differences ($p > 0.05$) between BIPOC and white students, or between any group broken down by race/ethnicity and gender (Fig. 6b).

I repeated these tests on the "performance/competence" component of the geoscience identity scores of BIPOC and white students and calculated a p-value of 0.02 (Table 3). This is moderate evidence against the null hypothesis that the two groups do not differ in their mean performance/competence component of their geoscience identity score. I calculated a small-medium effect size with a Cohen's *d* of 0.39. A 20% means-trimmed, bootstrapped one-way ANOVA found $F = 7.7$, $p < 0.01$, meaning the group means were not all equal. The effect size is Cohen's $f = 0.45$. A pairwise post-hoc test showed that white male students had significantly ($p < 0.05$) higher performance/competence scores than all other students. Female and non-binary students of all race/ethnicities fell into the middle of scores in the performance/competence component of geoscience identity and had higher ($p < 0.05$) scores than BIPOC male students, who scored the lowest of all groups (Fig. 6c).

My second research question examined experiences in a geoscience degree program that influence geoscience identity. I calculated descriptive statistics of the section of the survey involving Likert-type scale ratings of common experiences known to influence geoscience identity, including mean and standard deviation, the results of which are in Table 3. To see if the common experiences influencing geoscience identity were rated differently across race and gender demographics, I used a means-trimmed, bootstrapped ANOVA test on each factor's ratings (Table 4). Ten of the common experiences did not have statistically significant differences: "Learning use of tools, equipment, and other material resources", "Research experience (non-course-based)", "Course-based research experience", "Place-based geoscience courses", "Coursework incorporating cultural relevance and/or Indigenous knowledge", "Faculty mentors and role models", "Field experiences", "Gaining knowledge of geoscience careers", "Receiving support from family and peers", and "Feeling a sense of belonging; relating to

geoscience culture". Four of the fourteen common experiences had statistically significant differences in their ratings by different groups: "Feeling connected to the Earth" (Fig. 7a), "Seeing oneself represented in faculty and staff" (Fig. 7b), "microaggressions" (Fig. 7c), and "macroaggressions" (Fig. 7d). Female and non-binary BIPOC students were significantly different from other groups in all four experiences' ratings, rating "Feeling connected to the Earth" and "Seeing oneself represented in faculty and staff" more positively than white men. They also rated "microaggressions" and "macroaggressions" as more negatively affecting their geoscience identities than white men. Female and non-binary white students also rated "Seeing oneself represented in faculty and staff" more positively than white men and rated "macroaggressions" as more negatively affecting their geoscience identities than white men (Table 4; for all differences, $p < 0.05$).

5.2 Qualitative Results

The thirteen themes arising from thematic analysis were able to be diagrammed to address the second research question and further explore the elements of a geoscience program that influence geoscience identity. The themes described common experiences occurring on different scales, from characteristics of individuals to society-wide factors. As this range of themes aligns with ecological interpretations of school environments found in school-belonging research (e.g. Gray et al, 2018; Eccles & Roeser, 1998), I diagrammed the themes into different levels. The themes reflected the Opportunity Structures framework by Gray et al. (2018), which is a race-based framework examining the interpersonal, instructional, and institutional environments that engage or disengage Black adolescent students from feeling a sense of belonging.

Using these frameworks as guidance, I diagrammed the thirteen themes into four levels: individual, interpersonal, academic, and systemic (Fig. 8). The individual level contains themes that address feelings and identities held internally by survey respondents. The interpersonal level contains themes regarding one-on-one interactions or relationships with others. These can be considered as a student's micro-system level (Bronfenbrenner, 1974). The academic tier includes themes covering experiences at a meso-system level: classes, clubs, and other environments containing groups of people. The systemic level, the macro-level, includes themes covering experiences resulting from departmental or institutional factors, or direct references to dynamics of the broader geoscience field. Diagramming themes on these levels allows for analysis of the influence of educational factors at multiple levels on the individual, especially as it relates to geoscience identity.

The thirteen themes are ordered below by socio-ecological level (Bronfenbrenner, 1974), starting at the individual level and moving up to the structural level. Each level contains themes largely revolving around positive sentiments and themes largely revolving around negative sentiments: At the individual level: (1) interest/affinity for the Earth and (2) struggles with mental health/feelings of inadequacy; at the interpersonal level: (3) supportive relationships and (4) hostile/unsupportive interactions; at the academic level: (5) help with career preparation, (6) lack of career preparation, (7) engaging classroom experiences, (8) othering in geoscience courses, (9) issues with course/degree requirements, and (10) meaningful extracurricular activities; at the structural level: (11) exclusionary cultural/social dynamics, (12) community and belonging, and (13) structural barriers. The list of codes attributed to each theme, along with example text from responses, are in Table 5. Each theme is addressed separately below and illustrated with supporting quotations. Some racial groups were only represented by a few

respondents, but when possible, I compared the themes occurring in responses from different demographics. The percentage of responses pertaining to each theme are listed by race and ethnicity in Table 6, and are used to identify patterns where some racial/ethnic groups are over- or underrepresented in reporting experiences pertaining to each theme.

Interest/Affinity for the Earth

Survey respondents described their personal relationships with nature as a driving force in their academic journeys in geoscience. Some explained that their choice to major in geoscience was driven by feeling connected to the Earth: “Fell in love with rocks and national parks at a young age”, “Love of nature”, “I love the ocean and animals”. Similarly, the most common reason for choosing the major was personal interest in the subject matter: “I’ve been fascinated by plate tectonics since I was in middle school”, “Always loved learning about the process of the planet Earth”.

A desire to protect the environment or help people with the effects of natural hazards was another positive factor in students’ persistence in the major: “I want to help with climate change”, “I want to work outdoors, I love science, and I want to save the planet”, “My love for mountains and helping people with geological hazards”.

This theme was the most commonly occurring overall and had responses by students of different race/ethnicity groups as well as gender identities roughly proportional to their percentage of total survey respondents.

Struggles with mental health/feelings of inadequacy

Students described feeling inadequate or having general struggles with mental health, which negatively impacted their academic experiences. Students reported low geoscience or

math self-efficacy: “I have felt overwhelmed at times and have had feelings that I’m not good enough to succeed in geology”, “I felt incompetent in the field”, “I struggle with math and hard science courses”. Some specifically identified imposter syndrome: “Sometimes I feel imposter syndrome, like other people in my field know way more than me and are way more involved than me”.

These struggles with confidence in one’s academic abilities (or general effects of poor mental health) were often cited as a reason students considered leaving the major: “I have briefly considered [leaving the major] due to coming close to burnout”, “Sometimes I felt too stupid in classes, so it made me feel like I didn’t belong in the major”.

White male students, who were 19% of all respondents to open-ended questions, made up just 9% of the responses pertaining to this theme. BIPOC students, especially female and non-binary students, were more likely to report struggles with mental health and feelings of inadequacy.

Supportive relationships

Supportive interpersonal relationships with friends, family, and professors were often cited as elements that drove students to choose (and/or stay) in the geoscience major. Feeling encouraged and supported by mentors was commonly mentioned: “An aspect that helped me return to being a geoscience major was the fact that my faculty were so kind and supportive”, “My professors were an integral part of my experience”, “I have had some very supportive faculty who went out of their way to help me get more experience”. Making connections with students as well as faculty was also often mentioned as affirming factors: “It is easy to get to know other classmates and professors, and lots of people are willing to help me out when I need

it", "My classmates were lovely", "I also made a couple of friends in my courses. The company on this geoscience journey really made a difference".

This theme had responses by students of different race/ethnicity groups as well as gender identities roughly proportional to their percentage of total survey respondents.

Hostile/unsupportive interactions

Codes such as microaggressions and respect from professors (negative) coalesced into a theme of hostile or unsupportive interactions with others. The code 'microaggressions' refers to interactions with others, usually one-on-one, that involve discriminatory remarks, comments, or jokes. The code co-occurs with codes describing specific forms of discrimination, such as encounters with racism or encounters with sexism. Survey respondents describe being the target of comments based in prejudice: "Being a woman, I experienced several comments from male faculty about whether or not I will pursue teaching", "A professor who told me to my face he didn't think I was capable of doing research without ever having a conversation with me". Several responses used the term "microaggressions" outright: "I did receive micro aggressions as a member of the Latino community", "Experienced some microaggressions as a gay man".

When students referenced close relationships as having a negative impact on their progress towards a geoscience degree, it was usually in reference to juggling their family commitments, or not receiving support from their family: "Overwhelmed with school course load and family life", "I did consider leaving because my husband lives on the other side of the country (army)", "My family didn't support my dreams to become a geoscientist".

Responses pertaining to this theme were far more likely to come from female and nonbinary students: they represented 92% of respondents and were 68% of overall respondents.

Except for the Hispanic or Latino and Black or African American groups, all systemically non-dominant race/ethnicity groups were overrepresented in responses pertaining to this theme.

Help with career preparation

Some respondents discussed career preparation with positive sentiments. Students shared that being able to link their interests to a career or knowing there were jobs available was affirming: “Interest in the environment that can translate into employment”. In terms of students’ perception of the state of the geoscience job market or average salaries, some believed that pursuing geoscience jobs was advantageous: “I heard it was a field that needed more people”, “The job growth is good, and the pay is good”.

Opportunities to gain job experience, such as internships, were described positively. They were also linked to increasing student’s self-efficacy and feeling better prepared to enter the workforce: “I got the opportunity to try different aspects of geoscience through internships”, “Going out and gaining real-world experience in the career field via our local history museum has been the best thing I have ever done for myself and my career development”.

This theme had responses by students roughly proportional to their overall percentage of respondents with regards to gender identity as well as race/ethnicity with one exception. Hispanic or Latino students made up 11% of respondents pertaining to this theme despite being 20% of total respondents.

Lack of career preparation

Conversely to the previous theme, some students were discouraged or even considered leaving the major due to a lack of understanding about geoscience careers. This took the form of an incomplete understanding of the types of geoscience jobs available, or a belief that a

particular deficiency of theirs meant they should not pursue a geoscience career: “I didn’t know what I will do with the degree”, “Didn’t feel like the best fit and didn’t get introduced to careers until an internship”, “People say oil and gas but they never dive deep into exactly what the job description is or what aspects it will entail”.

In terms of salary, or the availability of jobs in the geoscience job market, some students had an unfavorable outlook: “[I considered leaving] for a more lucrative career”, “The job hunting is difficult”, “I was worried about careers”.

This theme was mentioned with equal frequency by male students vs. female and non-binary students and was not mentioned at all by students identifying as: Hispanic or Latino, Native Hawaiian or other Pacific Islander, or Other.

Engaging classroom experiences

Regarding the classroom, students described engaging course content and effective instruction as positive influences in their geoscience degree experiences. For some, good experiences in their introductory geoscience courses led to a decision to major: “My 101 prof was hyped about class and that got me hyped about class”, “Geology 101 was a great class and the first one in my education experience where I thoroughly enjoyed what I was learning”. Students often brought up positive experiences in class as a supporting factor in their educational journeys: “My teacher in HS would make it interesting to learn and I became fascinated with the subject”, “We did a lab with the stream table that I loved. I find studying the Earth to be very personally engaging”.

Field experiences were polarizing among geoscience students who took the survey. Some cited it as influential in helping them understand geoscience concepts or identify as a

geoscientist: “I love classes with field trips. They let me see in person applications better than in class theoreticals”, “Field experiences and research outside of courses solidified my identity as a geoscientist and student of the Earth”. Other responses, which are detailed in the next theme, were from students who found field experiences distressing: “I do not enjoy being out in the field… This made me feel like maybe I did not belong in the field of geoscience”.

Engaging classroom experiences, along with meaningful extracurricular activities (below) were the most common themes after interest/affinity for the Earth, and these three themes commonly co-occurred in survey responses. No respondents identifying as American Indian or Alaska Native, Black or African American, or Native Hawaiian or other Pacific Islander reported any engaging classroom experiences in their responses.

Othering in geoscience courses

Instances of othering, where a student was made to feel out of place or like an outsider, were reported by students in a variety of classroom scenarios. Some were instances of unequal treatment by instructors/TAs based on students’ gender identities: “I had TAs who dismissed my answers but not those of men”, “I received more criticism than male students”, “I do notice that despite scoring well on tests or projects, more opportunities are extended to male students, even ones who did not perform as well on some assignments”. Others discussed discrimination by professors while discussing their racial/ethnic identities: “As a member of the Latino community… I missed out on opportunities and was treated differently as my peers”, “I have faced discrimination from a professor once because I was/am different from the other students”.

The lack of inclusion of Indigenous knowledge and place names in geoscience courses was othering to students, particularly those from Indigenous cultures: “It is insulting sometimes

that we are studying the land of my ancestors and its never mentioned who lived in the national parks or owned them before people put a fence and a plaque on ol' faithful", "Sometimes I see people pull up pictures of places and landforms that are from my reservation and they don't even mention how my people have 20,000+ years of history in the area".

Bad experiences that students had in the field that turned them away from geoscience were also attributed to this theme: "Only [considered leaving the major] once during the field structural class. The professor made the experience awful", "Field experience was only negative because of [instructor]", "I felt incompetent in the field. The projects after the fieldwork also brought me a lot of stress".

Responses pertaining to this theme were far more likely to come from female and nonbinary students: they represented 92% of respondents in this theme and were 68% of overall respondents.

Issues with course/degree requirements

Several students reported considering leaving the geoscience major because they struggled with academics in their geoscience degree programs. Some issues arose from available courses in the students' interests or chosen sub-field: "My department did not support me and my major because it was not 'traditional' geology", "Sometimes it's hard to enroll because there isn't (sic) professors to teach the subjects, so I feel that I'm losing out". Other issues came from degree requirements or required geoscience courses: "My university's program is too rigid", "Courses are too rock heavy", "Mineralogy. That should answer it".

The math and science courses often required as part of a geoscience degree posed a problem to many students: "I couldn't seem to do well in calculus because it did not feel

applicable to my major", "I actually [left] but came back to [the major]. I struggle with math and hard science courses", "Physics rocked my GPA and I struggled to figure it out". Codes in this theme commonly co-occurred with the theme of struggles with mental health/ feelings of inadequacy.

White students made up 48% of respondents in this theme and were 66% of total respondents. White male students made up 7% of responses in this theme.

Meaningful extracurricular experiences

Research experiences outside of class was mentioned very frequently and in universally positive terms as a contributing factor to students' geoscience identities and persistence into careers or graduate school. Some students said working with a professor at their school was influential: "My advisor has given me the opportunity to work on my own research with him and write a thesis", "A huge help in my geoscience education has been my research work that I've been able to do. I work for a professor and it has been amazing to conduct my own research and make discoveries with the support of an expert. It's helped build my confidence in my abilities greatly".

Others found research experiences outside of their school to be important: "One of my most important experiences was participating in an REU", "A very kind professor from another university who got me involved in experimental petrology as a sophomore". One student credited these experiences with supplementing their knowledge of the field of geoscience beyond what they learned in their home department: "By having research experiences outside of my university I finally learned about the many things I can do and about all the possibilities".

Aside from research experiences, other geoscience experiences outside of courses had a positive impact, such as clubs or lab groups: “The geology club has helped me a lot in making connections to both my peers and faculty – as well as getting me outside in nature!”, “I was president of the geoscience club at my old school and that helped influence my decision to change majors”, “Lab groups where we read and analyzed scientific papers helped me more than I thought it would”, “Being a TA”.

White students were overrepresented in this theme (77% of respondents compared to 66% of the total). Responses by students’ gender identities were roughly proportional.

Exclusionary Social/Cultural Dynamics

Some students shared that the overall culture and space in their department – or their experience of geoscience culture in general – made them feel unwelcome or excluded. This often arose from experiencing cultural differences from the majority of students in their program: “I find very few people with my cultural background”, “I am from Hawai’i… but a lot of my classmates are from the mainland, so the cultural differences are noticeable”, “Everything is really disconnected, and I definitely feel alone most times in geoscience… I know it takes presences like mine to change that, but it’s hard”.

“Our building does not have a women’s bathroom on the second floor… women didn’t do research in labs, so they just never added a bathroom. To this day, 50 years later, there is still no bathroom, no matter how much we advocate for one”.

Some responses by students of extremely underrepresented groups in the geosciences could not be included, as the details they shared could of their experiences could lead to them being identified. No white male students reported experiences with exclusionary cultural/social

dynamics, and white female and non-binary students made up 55% of respondents in this theme while representing 47% of total respondents.

Community and Belonging

Many responses coalesced around students' feelings of belonging and fitting into a community within geoscience. This theme also includes responses that mention the culture of the student's geoscience department, or geoscience culture in general, that promote a student's sense of fitting in and belonging in the field. Students often mentioned feeling comfortable in their department's environment: "So much community in the geo group. It's awesome. And it doesn't feel competitive", "The faculty and the environment they cultivate is amazing", "I feel so at home with the faculty and with my peers".

Being able to identify with others or having their identities embraced in their departments was a factor in some students feeling a sense of belonging: "As a trans person I've felt very welcomed by my peers in this program. Makes me hopeful for my future in geoscience", "The high percentage of gender minorities as students in the geology department really helped me feel at home", "It's good to see representation and to feel included in geoscience as it helps me feel like I belong and that I'm able to keep up with other people who come from different backgrounds".

This theme had the highest differences in responses by demographic groups proportional to total responses. 80% of responses came from white students, who were 66% of total respondents, and the remaining responses came from students identifying as: Asian, More than one race, Native Hawaiian or other Pacific Islander. No responses regarding community and belonging came from students identifying as: Hispanic or Latino, American Indian or Alaska

Native, Black or African American, or Other. No BIPOC male students reported sentiments related to community and belonging.

Structural Barriers

Several structural barriers existing at the departmental, institutional, or societal level were cited as negative factors of students' experiences or factors that made them consider leaving the major. Some barriers were due to affordability: "I couldn't afford the field camp", "I considered other paths simply due to financial struggles". Some cited a lack of representation in faculty and staff: "I've never seen anyone like me in the geosciences, which is sometimes disheartening", "There were only two female [staff] in the geology department", "I would have enjoyed having more women to look up to".

Another structural barrier was physical accessibility issues, specifically around field courses: "I am fortunate enough to not have to do field camp, but every aspect of field work in the geology classes has accessibility issues that it doesn't seem they're even attempting to address", "I considered leaving my geoscience major because of my field classes. I am not able to go on long hikes due to chronic back and knee pain and would constantly fall behind during my field classes… I began to think that perhaps I was not 'cut out' to be a geoscientist/pursue my major."

A last structural barrier was effects of the Covid-19 pandemic and remote instruction: "Due to classes being online during Covid, I have very little field experience and worry about how I will perform as a geoscientist after receiving my degree", "The f****** pandemic made learning hard and I have no idea how much I learned over the past three years."

Almost every systemically non-dominant racial or ethnic group was overrepresented in responses pertaining to this theme. In particular, BIPOC male students made up 35% of respondents in this theme despite representing just 13% of total respondents.

5.3 Internalization of experiences at interpersonal/academic/systemic levels

Geoscience identity and related constructs like self-efficacy, occur within individuals but are influenced by experiences occurring at higher socio-ecological levels (White et al., 2018; Streule and Craig, 2016; Cooper et al., 2019). In many survey responses, students discussed feeling differently about their abilities, identities, or sense of fit within geoscience after impactful experiences in themes ranging from the interpersonal level to the systemic. This indicates an individual outcome of internalization of experiences occurring at higher socio-ecological levels. Two common pathways are described below: discordant or hostile experiences leading to more negative individual sentiments and thoughts of leaving the major, and positive and supportive experiences leading to a greater interest and sense of fit within the field.

Several students spoke about being “the only one who looks like me”, and some linked that extreme feeling of being different from everyone else to questioning whether or not they belonged in geoscience. These students identified as: American Indian or Alaska Native, Black or African American, More than one race, and/or Native Hawaiian or other Pacific Islander. Some of these students specified that they did not see anyone else in their geoscience departments that shared the combination of marginalized identities that they held. For example, one student shared, “I’ve never seen anyone like me in the geosciences which is sometimes disheartening. I have so far had one BIPOC/API teacher who was queer, and one white queer teacher. But I have never had a teacher with a mix like mine and is also transgender and queer like me”.

Other students of systemically non-dominant (Jenkins, 2017) groups reported feeling out of place or doubted their ability to perform well as a result of experiences where they were made to feel like an outsider. These experiences ranged across the themes of hostile/unsupportive interactions, othering in geoscience courses, or exclusionary social/cultural dynamics: "I do not enjoy being out in the field, while most of my peers do. This made me feel like maybe I did not belong in the field of geosciences", “Sometimes I feel like my professors don’t respect me for my knowledge and I am a bit self-conscious of how much geoscience knowledge I lack”. These responses illustrate a pattern of students internalizing experiences with discrimination, where experiences involving higher socio-ecological levels (systemic, academic, interpersonal) have a final negative outcome on the individual level. Almost every systemically non-dominant racial/ethnic category was over-represented in who reported experiencing struggles with mental health or feelings of inadequacy; BIPOC students overall represented 50% of these responses, despite only making up 34% of total survey respondents (Table 6).

Positive experiences occurring at higher socio-ecological levels also had outcomes on the individual level, with students expressing increased interest in geoscience and/or a desire to continue in the field after positive experiences. These ranged across the themes of supportive relationships, meaningful extracurricular activities, engaging classroom experiences, and community and belonging: “The faculty supported me a lot, and gave me a lot of opportunities to grow as a geoscientist over the years”, “By having research experiences outside of my university I finally learned about the many things I can do and about all the possibilities”, “Field experiences and research outside of courses solidified my identity as a geoscientist and student of the Earth”. Students identifying as Black or African American (n = 7) did not report any experiences falling into any of these four themes. Other systemically non-dominant groups did

report feeling encouraged by positive experiences with others, but at lower frequencies than white students. For two themes very commonly credited with enabling students to persist in the field – meaningful extracurricular activities and community and belonging – white students made up 77% and 80% of respondents mentioning experiences within those themes, respectively, while being 66% of total respondents.

5.4 Data Integration

I compared the qualitative findings with the quantitative analysis of common experiences influencing geoscience identity using a convergence coding matrix (Table 4; O'Cathain et al., 2010). I assessed the degree of fit between quantitative and qualitative results with three possible outcomes. The first was confirmation, where both sets of results confirm each other; the second was expansion, where the two sets of results overlap in some respects but diverge into different (yet still complementary) insights of a given phenomenon; the third was discordance, where the quantitative and qualitative results are inconsistent or contradict each other (Fetters et al., 2013). For each factor influencing geoscience identity, I reviewed the quantitative findings and compared them to the qualitative findings, which were distilled insights from thematic analysis, proportions of positive or negative sentiments, and responses of students from different demographic groups. The degree of fit designations can be found in the convergence coding matrix (Table 4).

I determined ten of the fourteen common experiences to have confirmation between quantitative and qualitative results, noting a few different types of relationships between the sets of results. Common experiences with a high mean rating, implying they were most commonly rated as having a strong positive impact on students' geoscience identities, were also most often discussed in positive terms by students in open-ended responses. Examples of these common

experiences are: “learning use of tools, equipment, and other material resources” and “research experience (non-course based)”. Common experiences with lower mean ratings that were still positive, including those with larger standard deviations, were discussed with a mixture of positive and negative sentiments by students. Examples of these common experiences are “gaining knowledge of geoscience careers”, “feeling a sense of belonging/relating to geoscience culture”, and “seeing oneself represented in geoscience faculty and staff”. Two common experiences, “microaggressions” and “macroaggressions”, had a negative mean rating and were discussed in universally negative terms in open-ended responses.

Of the remaining three common experiences, one had a discordant fit. “Coursework incorporating cultural relevance and/or Indigenous knowledge” received a very high mean rating, indicating students regarded it as having a strong positive impact on their geoscience identities, but it was only brought up once in open-ended responses. The experience shared was a negative one, as land-based knowledge that did come up in class was discussed “in a very clinical way that is disconnected from the people who owned the land”. The remaining two common experiences, “course-based research” and “place-based geoscience courses” did not receive a fit rating as they did not have correlating qualitative results.

5.5 Content Analysis

To aid in data integration, I transformed relevant portions of the qualitative data into numeric counts using content analysis (Krippendorff, 2013). This involved counting the frequencies of codes occurring within each theme (Table 4), and the frequencies of themes occurring in responses to specific survey questions. I analyzed responses to the survey question, “Did you ever consider leaving your geoscience major? If so, why?” Students who had considered leaving their geoscience major at some point in their undergraduate experience (n =

47) cited a range of reasons why they almost left. The most common reasons fell into the themes of struggles with mental health/feelings of inadequacy (n = 16), and issues with course/degree requirements (n = 12). Next in frequency was lack of career preparation (n = 8) and structural barriers (n = 7). The White racial category was the only group to have proportionally fewer students respond that they considered leaving the major (Table 6). BIPOC students, despite making up only 34% of total survey respondents, made up 56% of respondents who considered leaving the major because of struggles with mental health or feelings of inadequacy, and 71% of respondents who considered leaving because of structural barriers (Table 6). The other main reasons cited for considering leaving the major – issues with course/degree requirements and lack of career preparation – had more proportional representations in terms of race/ethnicity demographics of respondents.

6. Discussion

This study measured geoscience identity in undergraduates and examined the common experiences of an undergraduate geoscience degree program that influence geoscience identity. Because many students begin developing individual characteristics related to geoscience identity before beginning an undergraduate degree, prior experiences may have influenced the survey respondents' geoscience identity scores or responses covering themes on the individual level. For example, students reporting struggles with mental health and feelings of inadequacy may have experienced them prior to their geoscience degree program, and it is unknown if those feelings continued at the same level or were exacerbated while they completed their undergraduate degree. Research aimed at broadening inclusion in geoscience has found pre-college factors that contribute to low diversity in geoscience, such as unequal exposure to geoscience and geoscience career options prior to starting an undergraduate degree (Carrera, 2023). Geoscience

departments, therefore, are tasked with correcting the effects of structural racism that occur before a student even enters their program as well as those present in the program itself. Anti-racism efforts in geoscience must also target barriers occurring at the K-12 level.

Consistent with science identity studies in other STEM disciplines (Hazari et al., 2013; Chang et al., 2011; Carlone and Johnson, 2007), BIPOC students identified as geoscientists less strongly than their white peers. White students had stronger geoscience identities than BIPOC male students, with much of the difference concentrated in the performance/competence domain of geoscience identity. This differs from other studies that emphasize the recognition domain as more influential in determining differences in geoscience identity between BIPOC and white scientists (Godwin et al., 2016; Carlone and Johnson, 2007; Gee, 2000). A potential explanation for this difference is the high value placed on performance & competence by the survey respondents, as many discussed the importance of their ability to gain geoscience competencies in hands-on settings and then perform relevant geoscience practices in field experiences and research. This emphasis on students' perceptions of their performance and competence in geoscience is consistent with literature on the impact of field and research experiences on undergraduates' identity formation and persistence in geoscience (Cooper et al., 2019; Kortz et al., 2019; Streule and Craig, 2016).

The finding that BIPOC students' geoscience identities are significantly lower than those of white students speaks to issues of racial equity that go beyond diversity and representation. The results of this study's qualitative and quantitative exploration of common experiences that influence geoscience identity offer insights into why these disparities in geoscience identity occur across race as well as gender demographics and will be discussed below. Although representation on its own was found to impact students' sense of belonging, several cultural and

structural factors contribute to an environment where BIPOC students, especially female and non-binary BIPOC students, endure more discrimination and are less likely to access positive, formative experiences in their geoscience programs.

6.1 Racism harms BIPOC students' geoscience identities

BIPOC students reported experiencing discrimination from professors and other types of microaggressions/ macroaggressions more often than white students, and they indicated that it negatively impacted their geoscience identities. Hostile climates for BIPOC students in geoscience are widespread and well-documented (Morris, 2021; Dutt, 2019; Marín-Spiotta et al., 2020). Qualitative findings showing BIPOC students believing they did not have what it takes to be a geoscientist after encountering discrimination are especially alarming, as it shows evidence of students internalizing racism – explicit or implicit – that they are encountering during their degree programs.

Above interpersonal interactions, BIPOC students reported classroom or extracurricular experiences that made them feel like an outsider or were challenging to their worldview or cultural background. For example, students identifying as American Indian or Alaska Native and/or Native Hawaiian or other Pacific Islander shared that their instructors and classmates treated Indigenous land, placenames, and knowledge insensitively, or did not acknowledge them at all. Course content and instruction that continues the erasure of Indigenous land and knowledge sends a message to Indigenous and non-Indigenous students alike that there is not a place for Indigenous cultures, knowledge, or people in geoscience (Nuñez et al., 2019; Graham et al., 2022).

BIPOC students reported feeling like they didn't belong in their department or in the broader field of geoscience more often than white students did. Many attributed it to having a background different from the vast majority of their peers or not seeing themselves represented in faculty and staff. The only white students who reported feeling out of place identified as female or non-binary. This indicates that the lack of diversity in geoscience departments (Beane et al., 2021; Bernard and Cooperdock, 2018) has a profound personal effect on systemically non-dominant students by hindering their abilities to see themselves in the field.

The prevalence of sexism in undergraduates' experiences, which also ranged from the interpersonal to systemic, adds an additional dimension of inequity to female and non-binary BIPOC students (Crenshaw, 1991, Nuñez et al., 2019). Demeaning comments, preferential treatment to male students in class, absence of female professors or other role models, and, even in one school's case, a lack of female restrooms in the geoscience department illustrate the span of sexism from interpersonal interactions to entrenched systems (Stokes et al., 2015). These barriers, coupled with entrenched racism in geoscience, present female and non-binary BIPOC students with a "double-jeopardy" of oppression that has been found throughout geoscience (Clancy et al., 2017, Marín-Spiotta et al., 2020).

Although no female and non-binary BIPOC students overtly discussed feeling the synergistic effects of racism and sexism in their open-ended responses, their responses in the section of the survey rating experiences that impacted their geoscience identities show a pattern of being discouraged by discrimination. Female and non-binary BIPOC students rated microaggressions and macroaggressions as more negatively impacting their geoscience identities than any other group. A higher proportion of white students chose the option "N/A: Did not experience this" for microaggressions and macroaggressions, indicating that not only are their geoscience identities

less discouraged by acts of discrimination, but that they experience less discrimination in general. Male BIPOC students had the lowest proportion of "N/A" responses, but the majority of their ratings of microaggressions and macroaggressions were the choice "Had neither a positive nor a negative effect on my geoscience identity", indicating that their geoscience identities are less affected by discrimination.

Female and non-binary BIPOC students, then, sit at the nexus of experiencing discrimination often and being provided the fewest supports to overcome it. This study's qualitative analysis, it revealed that white female and non-binary students are more likely to have supportive relationships and transformative experiences, as well as feel a sense of community or belonging in their geoscience department. Statistically, they (and male BIPOC students) are more likely to see themselves represented in faculty and staff (Nelson, 2017), which students rated as having a positive impact on their geoscience identities. Viewing these results at each socio-ecological level shows that female and non-binary BIPOC students are forging their geoscience identities with the fewest social and cultural resources while facing the most barriers, particularly at the structural level.

6.2 White students have more transformative experiences than BIPOC students

White students were much more likely to report benefitting from transformative opportunities. These were experiences that were rated as having a strong positive influence on students' geoscience identities, such as research experiences, learning how to use material resources, and field experiences. This indicates that some of these high-impact opportunities may be more accessible to white students, or that they are simultaneously creating more positive experiences for white students and more negative ones for BIPOC students. Barriers to fieldwork for BIPOC students have been explored in the literature (Anadu et al., 2020; Giles et al., 2020),

but more research is needed on disparate access to or experiences in transformative geoscience activities. For example, the design and outcomes of research opportunities for undergraduates are well studied (Gamage et al., 2021; Cooper et al., 2019; Burnley et al., 2018), but there is less known of how opportunities for undergraduate research are advertised or an evaluation of equity in recruiting undergraduates to conduct research with faculty mentors.

6.3 Recommendations

Anti-racism efforts led by BIPOC geoscientists have produced a wealth of recommendations and action plans for geoscience organizations looking to improve racial and gender equity (Todd et al., 2022; Ali et al, 2021; Nuñez et al., 2019; Huntoon and Lane, 2007). I expand on several of their recommendations that are especially pertinent to encouraging BIPOC students' geoscience identity below.

Listen to BIPOC students, and hold perpetrators of discrimination accountable

As is evidenced by the qualitative findings of this study, students' unique identities provide them with a vantage point through which they experience their geoscience degree programs. Affirming students' multiple dimensions of identity and providing a space where they can share their experiences is the first step (Ali et al., 2021) in addressing issues of inequity that are discouraging geoscience identity formation.

Members of geoscience communities who perpetrate microaggressions and harassment onto systemically non-dominant geoscience students are rarely held accountable (Marín-Spiotta et al., 2020). Many survey respondents in this survey reported hostile interactions where others who were present, including faculty, did not intervene. A collective effort to shift towards a mindset of talking openly about racism and other systems of oppression, and interrupting

instances where they are perpetuated, would improve geoscience departments for everyone (Dutt, 2020). Adapting ethics and conduct codes within geoscience departments and clearly communicating them (and, if applicable, the steps to be taken when they are broken) to all members is one way to set expectations for respectful and inclusive behavior in the department. Establishing a code of conduct also necessitates maintaining an environment where community members can voice concerns. Finally, codes of conduct must be enforced.

Make geoscience curricula and course experiences equitable and inclusive

Similar to the above recommendations for addressing discrimination in interpersonal interactions, geoscience departments can remove barriers to success for systemically non-dominant students in courses and course requirements. Improving equity and accessibility in field experiences is a priority, as the cost (Giles et al., 2020), physical requirements (Stokes et al., 2019), backcountry setting (O'Connell and Holmes, 2011), prevalence of sexual harassment (Clancy et al., 2014), and potential exposure to racialized or anti-LGBTQ violence (Anadu et al., 2020) poses barriers to students with a multitude of identities. Field experiences addressing at least some of these barriers have already enjoyed success while maintaining academic rigor (e.g. Gilley et al., 2015), and can offer guidelines for improving field-based learning. Field experiences were polarizing for survey respondents in this study, with the majority of positive experiences reported by white male students. As field experiences are so transformative for students' geoscience identities, it is imperative to give students of any identity the opportunity for a positive experience in the field.

Geoscience departments can adapt culturally responsive pedagogies to all courses to enable BIPOC students to better identify with the field (Davies et al., 2022; Sigman et al., 2014). Much research has focused on improving geoscience curricula to incorporate Indigenous

knowledge, cultures, and land, and to address geoscience's legacy of extraction and exploitation (Semken, 2018; McKinley et al., 2022; Todd et al., 2023). Geoscience departments should consider the integration of Indigenous knowledge, place-based education, and respect and acknowledgement of the Indigenous peoples whose land they occupy and study on.

Increase and improve recruitment and mentoring of BIPOC faculty

Just 13.6% of tenure-track geoscience faculty are BIPOC (Nelson, 2017), and the geosciences award the lowest percentage of PhDs to BIPOC scholars than any other STEM field (Bernard and Cooperdock, 2018). Improving diversity in faculty ranks allows BIPOC geoscience students to see themselves in the field (Ali et al., 2021; Baber et al., 2010) which is critical for geoscience identity formation. Mentoring and supporting BIPOC faculty is an important step in ensuring BIPOC students have role models and mentors who look like them, as BIPOC faculty are also harmed and excluded by systemic racism in geoscience (Morris, 2021; Dutt, 2020; Marín-Spiotta et al., 2020). Geoscience departments looking to recruit and retain BIPOC faculty should create partnerships and recruitment systems with MSIs (Morris, 2021) and learn from the successes of diverse geoscience departments (Morris et al., 2012).

6.4 Limitations

Survey-based studies by their nature face a number of limitations, such as an inability to follow-up with survey respondents for clarity or additional insights. This study was limited in particular by the inability to compare student responses to the type of institution where they studied, as protecting student anonymity meant the survey could not collect any potentially identifying information. The 99 universities that received this survey represent a cross-section of schools in terms of size, population served, and geographic location. There are large cultural and

social differences documented across these categories of institutions (Marín-Spiotta et al., 2020; Morris et al., 2012), with the most relevant to this study being the different experiences afforded to BIPOC and white students by predominantly white institutions (PWIs) and MSIs (Beane et al., 2021; Robinson et al., 2018). This study, therefore, can only make generalizations about the experiences afforded to BIPOC students in geoscience departments in the United States. The anonymous nature of this survey makes it difficult to discern how broadly the varying institutions are represented in the data set. The data set, however, represents a more racially diverse population than the overall population of geosciences major nationwide and provides valuable and needed information on the experiences of BIPOC students.

Another limitation of this study was the low number of respondents in some specific racial categories. Although individuals' responses to open-ended questions could be analyzed qualitatively, performing quantitative analysis necessitated grouping these students into the broad category of BIPOC. Although using the categories of BIPOC and white still allowed me to compare the experiences of students from systemically non-dominant and systemically dominant racial/ethnic groups, it means I could not pinpoint aspects and variations in geoscience identity for students from a specific racial or ethnic background. The qualitative data represent a collection of lived experiences of students that is needed in the field (Ali et al., 2021), but cannot speak for entire populations of people who share aspects of those students' identities. Because the quantitative results largely support the themes and patterns that emerged from qualitative analysis, it can be reasonably understood that the lived experiences shared are not outliers and are indicative of broader social and cultural aspects of the field.

White male students comprised the smallest group of survey respondents despite their large overall proportion of geoscience students nationwide. A potential explanation is the self-selecting

nature of surveys, as some types of students may have chosen to share their thoughts in the survey more than others given the survey's topic. Although the small number of responses means the results may not be representative of all white male students in geoscience, the group's high scores in geoscience identity provide important insights into how geoscience departments advantage white male students by fostering their geoscience identities.

The choice of survey population presents a limitation to this study and an opportunity for future research. Eliciting responses from graduating seniors had practical benefits, as they are easily reachable through department listservs. This, however, limited the study to students who had successfully persisted through their undergraduate geoscience degree, thereby losing the input of students who were pushed out of the major entirely. Future studies able to reach students who left the major could collect experiences that could further illuminate how structural inequities push systemically non-dominant students out of the field.

7. Conclusion

BIPOC students in geoscience face discrimination and barriers to learning at all levels, from microaggressions to systemic racism. They are also less likely to have positive, transformative experiences than their white peers. Themes of experiences that either support or thwart students' geoscience identity formation and persistence in geoscience occur at all socio-ecological levels of undergraduates' learning environments. Efforts to improve diversity, equity, and inclusion in the field should prioritize creating environments free of harassment and remove structural barriers to learning for systemically non-dominant students. Improving access to positive, transformative experiences and increasing representation in faculty and staff will allow

BIPOC geoscience students to develop stronger identities as geoscientists and envision a future in the field.

The adaptation of the Geoscience Identity theoretical framework provides a strong centralizing structure that builds on the rich body of literature on science identity (e.g. Carlone and Johnson, 2007; Hazari et al., 2010). The greater differences in scores in the performance/competence domains of geoscience identity across race/gender demographics is a departure from studies in other STEM disciplines that emphasize recognition as a decisive domain of geoscience identity (Godwin et al., 2016; Carlone and Johnson, 2007; Gee, 2000). Further studies of geoscience identity could help to tease out variations in the dimensions of identity formation specific to the field.

The creation of the geoscience identity survey tool creates an opportunity for future research, as this survey can be reused in different contexts and with different populations of interest. Geoscience identity can be measured with this survey while, for example, collecting different demographic information regarding physical ability, sexual orientation, and a host of other identities that students hold. With care, researchers can also elicit survey respondents to identify the type of university or college they attend (e.g. PWI or MSI, size, public or private) so that analysis of experiences at different types of institutions can be conducted. Different open-ended questions can be posed for different qualitative explorations, or the tool can be used alongside other validated measures of student learning such as self-efficacy, motivation, or career choice.

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Figures and Tables

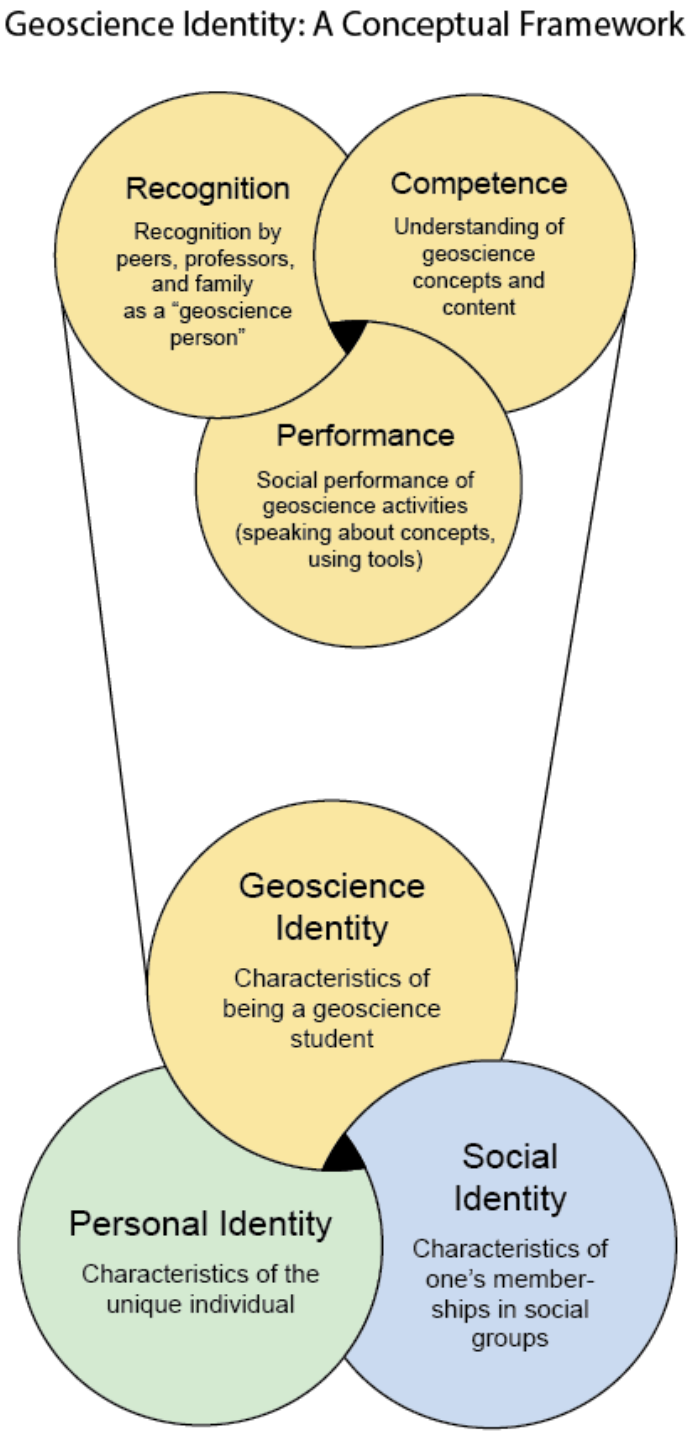


Figure 1. Conceptual model of the formative components of a student's geoscience identity. A student's geoscience identity is composed of three primary domains: recognition, performance, and competence. Geoscience identity is then combined with a student's social and personal identities to provide a holistic model of a student's overall identity. Figure adapted from Hazari et al (2010), which is based on the Science Identity theoretical framework by Carlone and Johnson (2007).

Survey Items Measuring Geoscience Identity

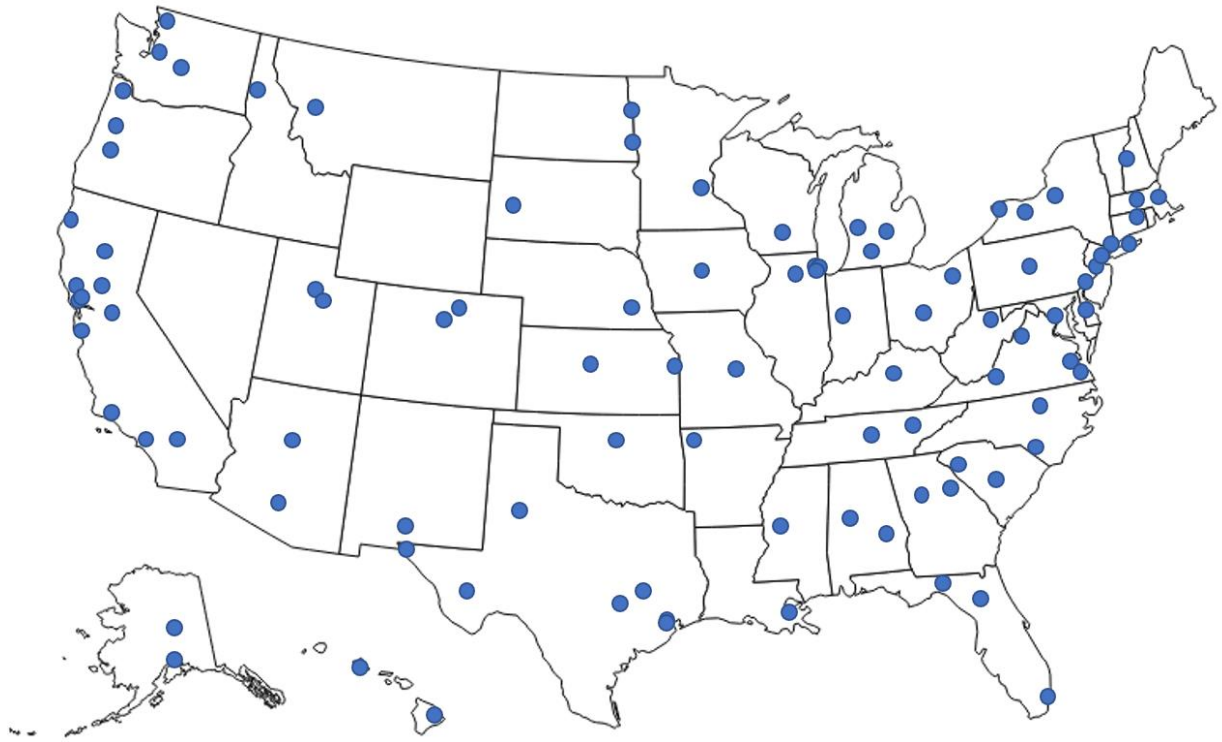
Recognition
I identify as a geoscientist
I am comfortable identifying myself as a geoscientist
My field of study helps me identify as a geoscientist
My faculty members recognize me as a geoscientist
My peers recognize me as a geoscientist
My family and friends recognize me as a geoscientist
It is not important to me that others see me as a geoscientist
Seeing other people who look like me within my field reinforces my geoscience identity
Doing geoscience is not important to who I am

(adapted from Williams and George, 2014)

Performance/Competence
I am confident that I can understand geoscience in class
I am confident that I can understand geoscience outside of class
I can do well on exams and projects in geoscience
I do not understand concepts I have studied in geoscience
Others ask me for help in geoscience
I cannot overcome setbacks in geoscience

(adapted from Godwin et al., 2016)

Figure 2. List of survey questions measuring strength of geoscience identity. "Recognition" and "Performance/Competence" sections were each validated in science identity studies by Williams and George (2014) and Godwin et al. (2016), respectively.



Arizona State University	Northwestern University	University of Georgia
Auburn University	Ohio State University	University of Hawai'i at Manoa
Brigham Young University	Oklahoma State University	University of Hawaii, Hilo
California State University, Chico*	Old Dominion University	University of Houston
California State University, Fullerton*	Oregon State University	University of Idaho
California State University, Sonoma State	Penn State University	University of Illinois at Chicago
Central Washington University	Portland State University*	University of Kansas
City College of New York	Purdue University	University of Kentucky
Clemson University	Rice University	University of Maryland
Colorado State University	Rutgers University	University of Massachusetts, Amherst
Colorado University, Boulder	San Francisco State University	University of Miami
Dartmouth College	Savannah State University*	University of Minnesota
Drexel University	South Dakota School of Mines & Technology	University of Missouri
Florida International University	State University of New York, Buffalo	University of Montana
Florida State University	State University of New York, Stony Brook	University of Nebraska-Lincoln
Fort Hays State University	State University of NY, Geneseo	University of New Orleans

Georgia Institute of Technology	Sul Ross State University	University of North Carolina at Pembroke
Georgia State University	Syracuse University	University of North Dakota
Grand Valley State University	Texas A&M University	University of Oregon
Humboldt State University	Texas Tech University	University of Puerto Rico*
Iowa State University	University of Alabama	University of South Carolina
James Madison University	University of Alaska, Anchorage	University of Tennessee-Knoxville
Kent State University	University of Alaska, Fairbanks	University of Texas, Austin
Massachusetts Institute of Technology	University of Arkansas	University of Texas, El Paso
Michigan State University	University of California, Berkeley	University of the Pacific
Middle Tennessee State University	University of California, Davis	University of Utah
Mississippi State University (MS)	University of California, Riverside*	University of Washington
Montclair State University	University of California, Santa Barbara*	University of Wisconsin, Madison
New Mexico State University	University of California, Santa Cruz	Virginia Institute of Technology
North Carolina Central University	University of Chicago	West Virginia University
North Dakota State University	University of Connecticut	Western Washington University
Northern Arizona University	University of Delaware	Western Michigan University
Northern Illinois University	University of Florida	William and Mary College

Figure 3. University and college recipients of the Geoscience Identity Survey (map and table). List of recipients generated from the American Geosciences Institute's report, "Status of Recent Geoscience Graduates" (Wilson, 2019). Schools marked with an asterisk are additional minority-serving institutions (MSIs) that were added in an effort to receive more responses from BIPOC students.

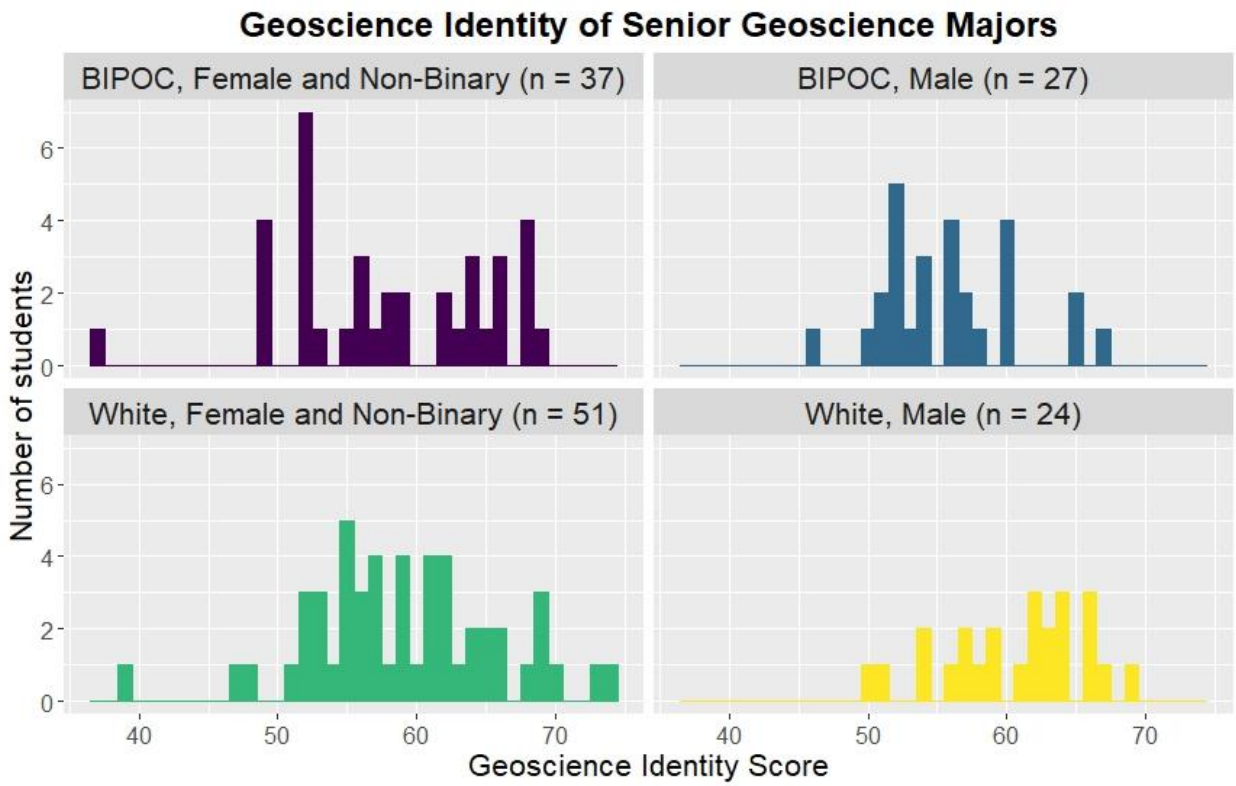


Figure 4. Histograms with distributions of students' scores in the measure of geoscience identity. Non-normal distributions, particularly the bi-modal distribution in the female and non-binary BIPOC group, violate assumptions of standard parametric statistical tests.

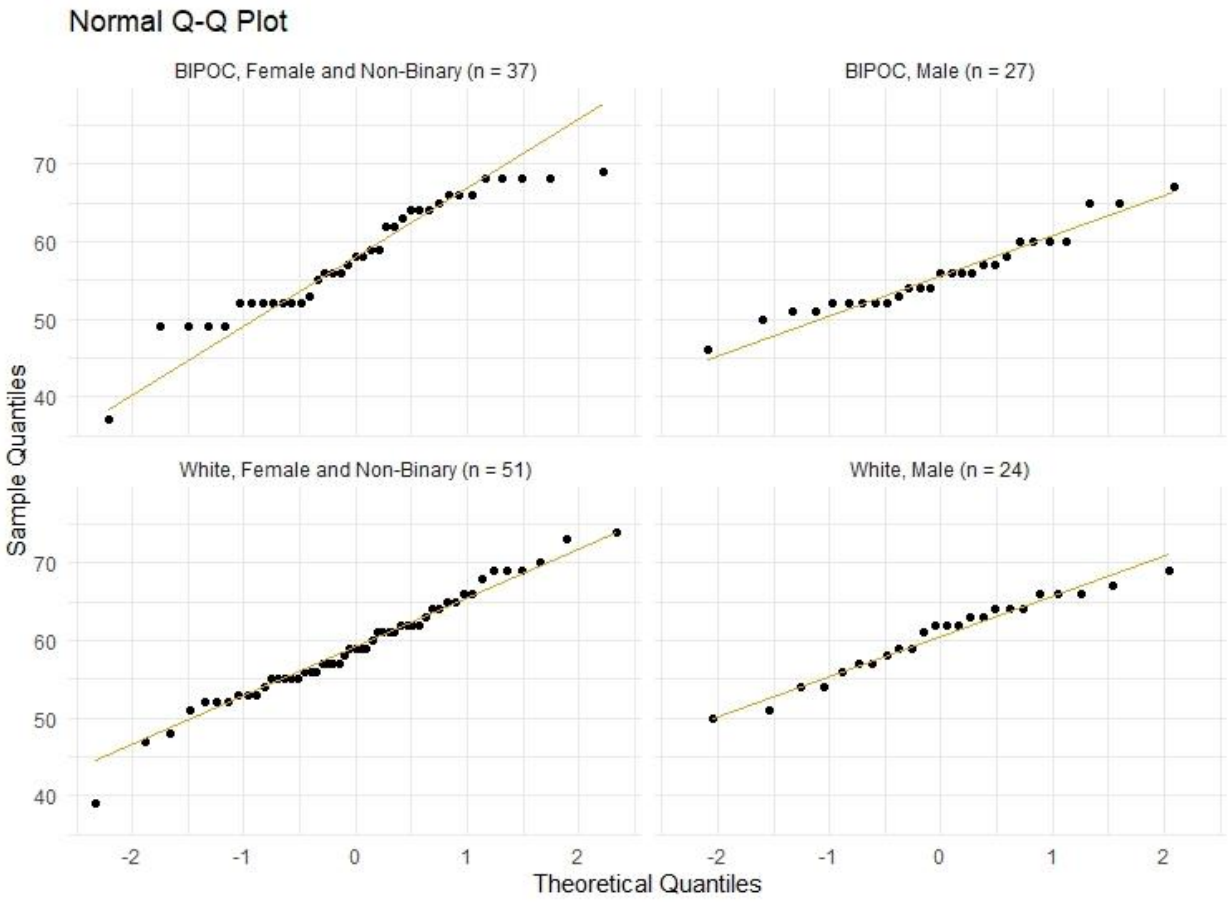
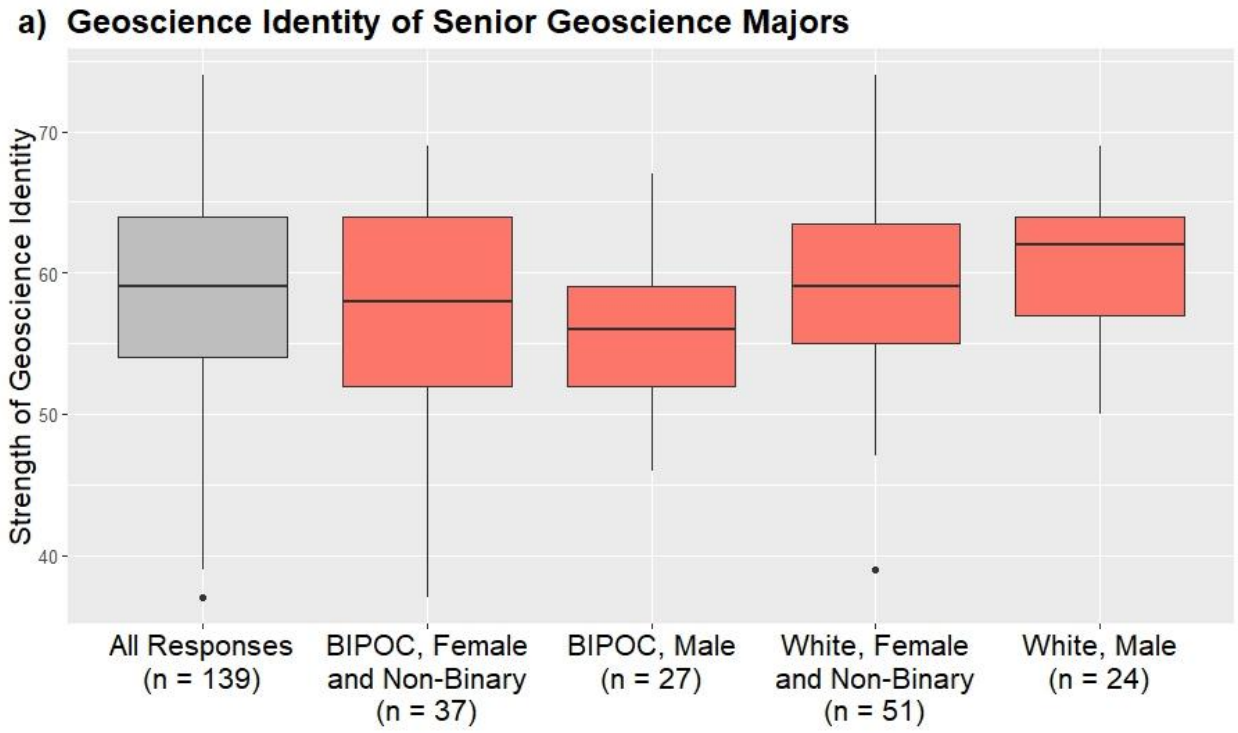


Figure 5. Normal Q-Q plot showing sample quantiles plotted over theoretical quantiles of a normal distribution. Plot points falling outside of a 45® line, specifically in the Female and non-binary BIPOC group, indicate a non-normal distribution.



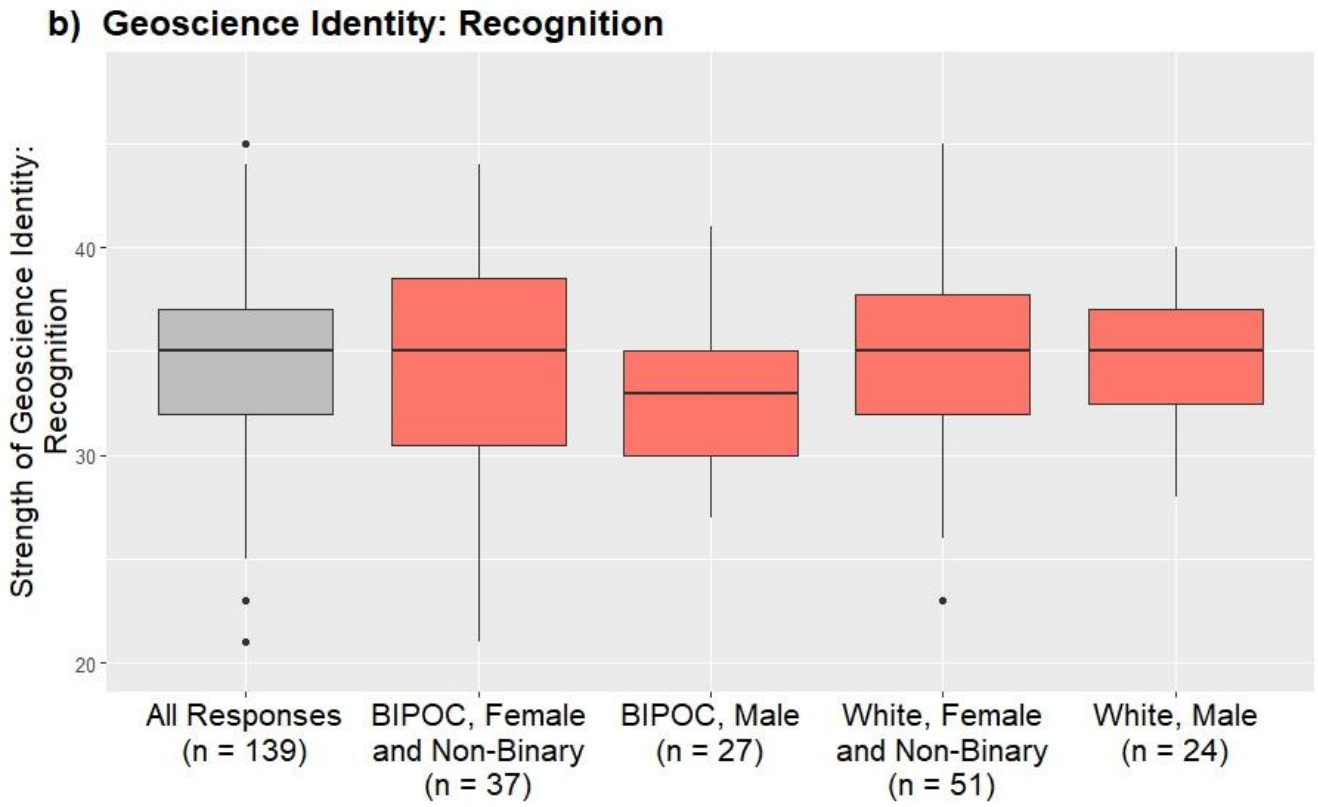
Post-hoc tests—pairwise comparisons of race/ethnicity and gender groups' mean geoscience identity scores

				95% Confidence Interval	
Group 1	Group 2	psihat	Sig.	Lower Bound	Upper Bound
Male White	FNB White	2.13	0.19	-5.94	2.17
	Male BIPOC	5.82***	<1e-5	-9.58	-1.50
	FNB BIPOC	2.93	0.14	-7.57	2.31
FNB White	Male BIPOC	3.7**	0.01	-7.11	0.23
	FNB BIPOC	0.81	0.66	-5.42	3.97
Male BIPOC	FNB BIPOC	-2.9	0.12	-1.93	7.54

FNB = Female and Non-Binary; BIPOC = Black, Indigenous, and People of Color

**$p < 0.01$

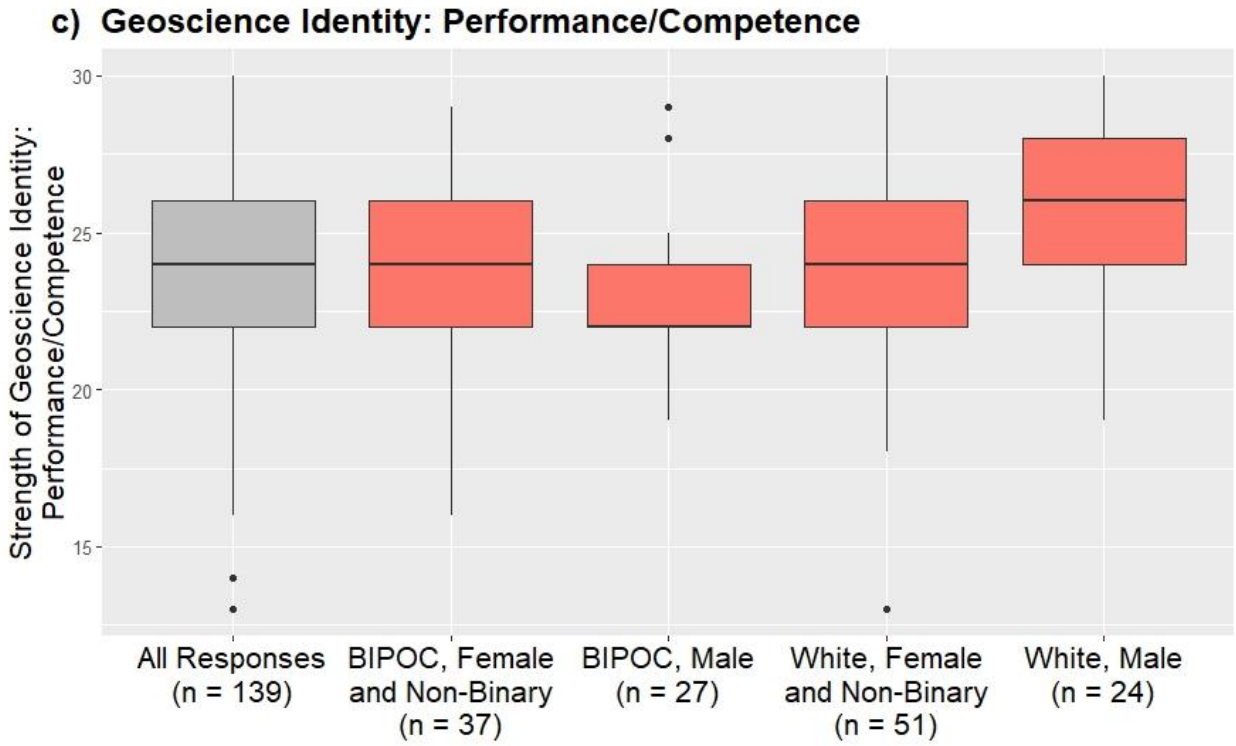
***$p < 0.001$



Post-hoc tests—pairwise comparisons of race/ethnicity and gender groups' mean geoscience identity scores in recognition

				95% Confidence Interval	
Group 1	Group 2	psihat	Sig.	Lower Bound	Upper Bound
Male White	FNB White	0.10	0.94	-2.50	2.77
	Male BIPOC	2.18	0.09	-5.12	1.09
	FNB BIPOC	0.22	0.87	-3.67	3.15
FNB White	Male BIPOC	2.08	0.07	-5.07	0.96
	FNB BIPOC	0.12	0.9	-3.55	2.87
Male BIPOC	FNB BIPOC	-1.96	0.19	-1.85	5.47

FNB = Female and Non-Binary; BIPOC = Black, Indigenous, and People of Color



Post-hoc tests—pairwise comparisons of race/ethnicity and gender groups' mean geoscience identity scores in performance/competence

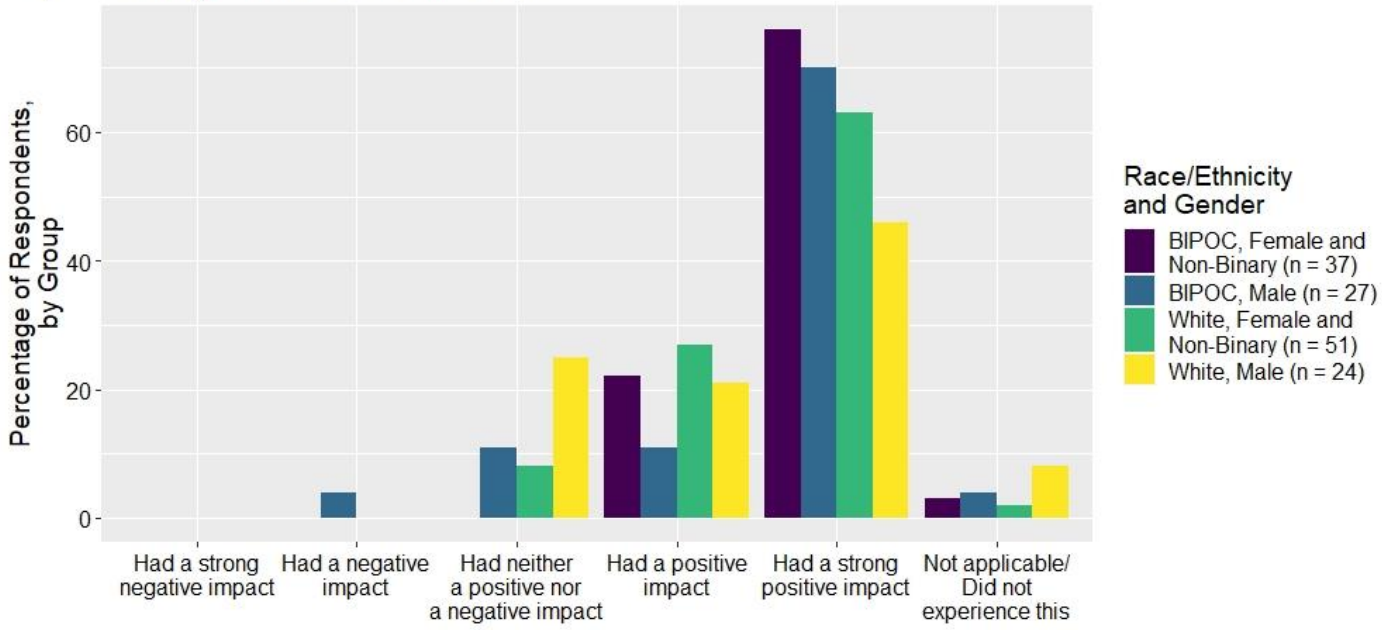
				95% Confidence Interval	
Group 1	Group 2	psihat	Sig.	Lower Bound	Upper Bound
Male White	FNB White	2.06*	0.02	-4.08	0.33
	Male BIPOC	3.24*	2.00E-04	-5.13	-1.03
	FNB BIPOC	1.98*	0.02	-4.12	0.22
FNB White	Male BIPOC	1.08*	0.03	-2.75	0.33
	FNB BIPOC	0.09	0.96	-1.92	1.73
Male BIPOC	FNB BIPOC	-1.26*	0.05	-0.47	2.76

FNB = Female and Non-Binary; BIPOC = Black, Indigenous, and People of Color

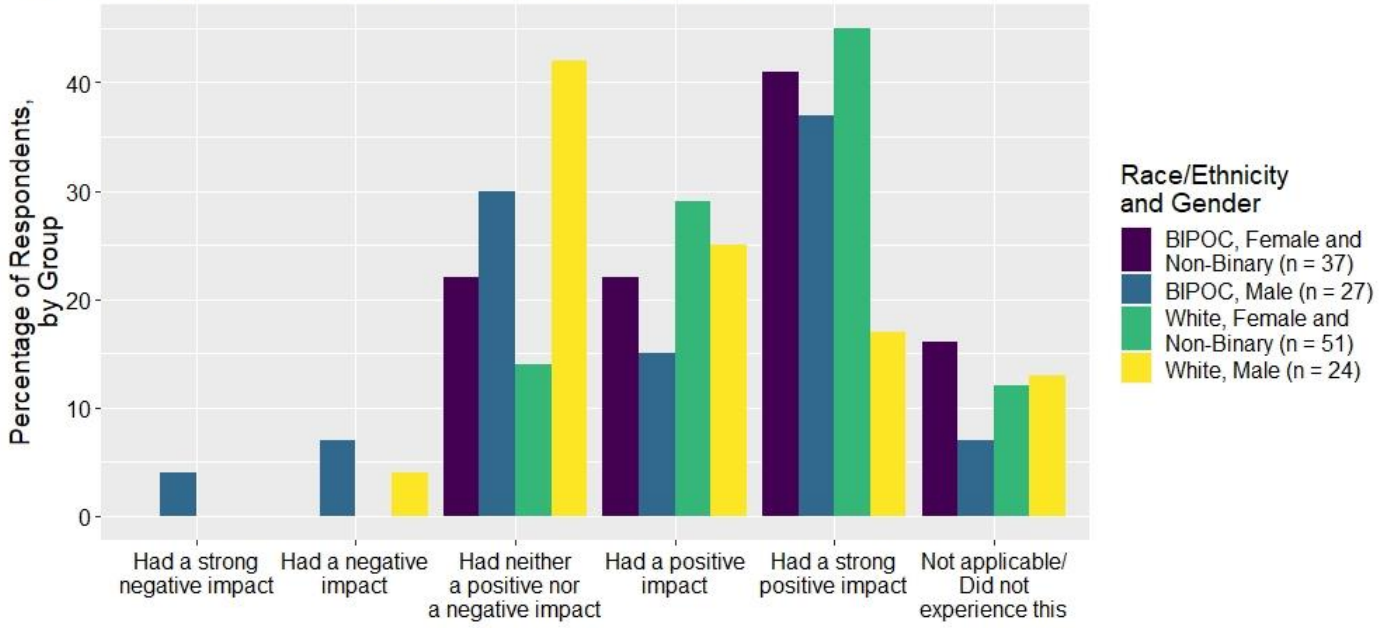
*$p < 0.05$

*Figure 6: Geoscience identity scores by race/gender groups, with accompanying pairwise results from post-hoc test (mean, SD, and psihat or differences in trimmed means). Significant relationships marked as follows: *p<0.05, **p<0.01, ***p<0.001; a) Complete geoscience identity scores. Male BIPOC students have, on average, lower geoscience identities than female and non-binary white students (p=9e-3) and white male students (p=8e-4); b) scores of the recognition component of geoscience identity, with no significant differences present; c) composite scores of the performance and competence components of geoscience identity. White male students have higher performance/competence scores than all other groups, female and non-binary students of all race/ethnicity groups fall into the middle range of scores, and Male BIPOC students have lower performance/competence scores than all other groups (for all performance/competence differences, p<0.05)*

a) **Feeling Connected to the Earth**



b) **Seeing Oneself Represented in Faculty & Staff**



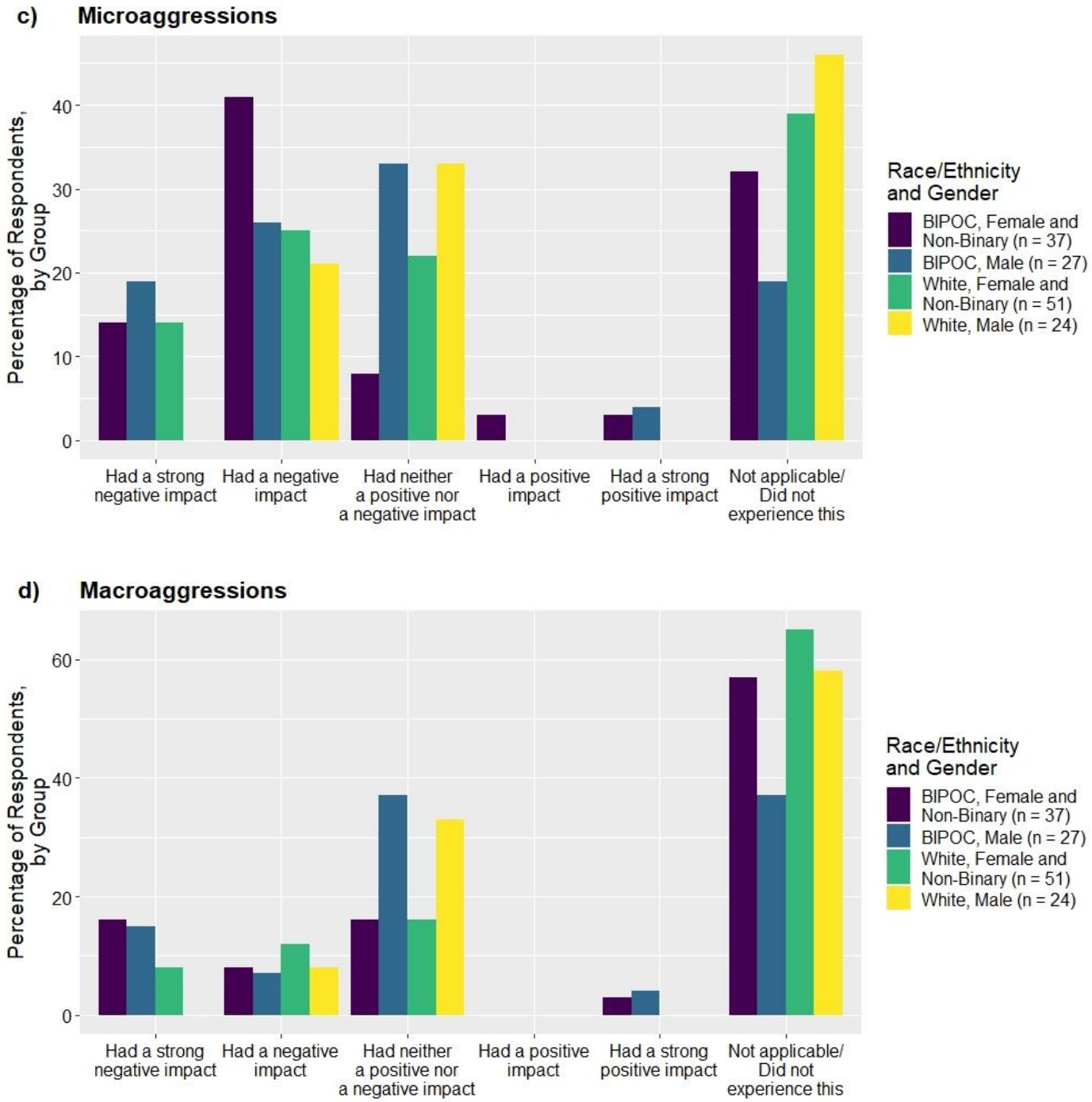


Figure 7. Four of the fourteen common experiences known to influence geoscience identity were rated differently by students of different race/ethnicity and gender demographic groups: a) Female and non-binary BIPOC students rated "feeling connected to the Earth" more positively than white male students; b) Female and non-binary students of all race/ethnicity groups rated "seeing oneself represented in faculty and staff" more positively than white male students; c) Female and non-binary BIPOC students rated "microaggressions" more negatively than white male students; d) Female and non-binary students of all race/ethnicity groups rated "macroaggressions" more negatively than white male students. Descriptive statistics and results from bootstrapped ANOVA tests are shown in Table 4.

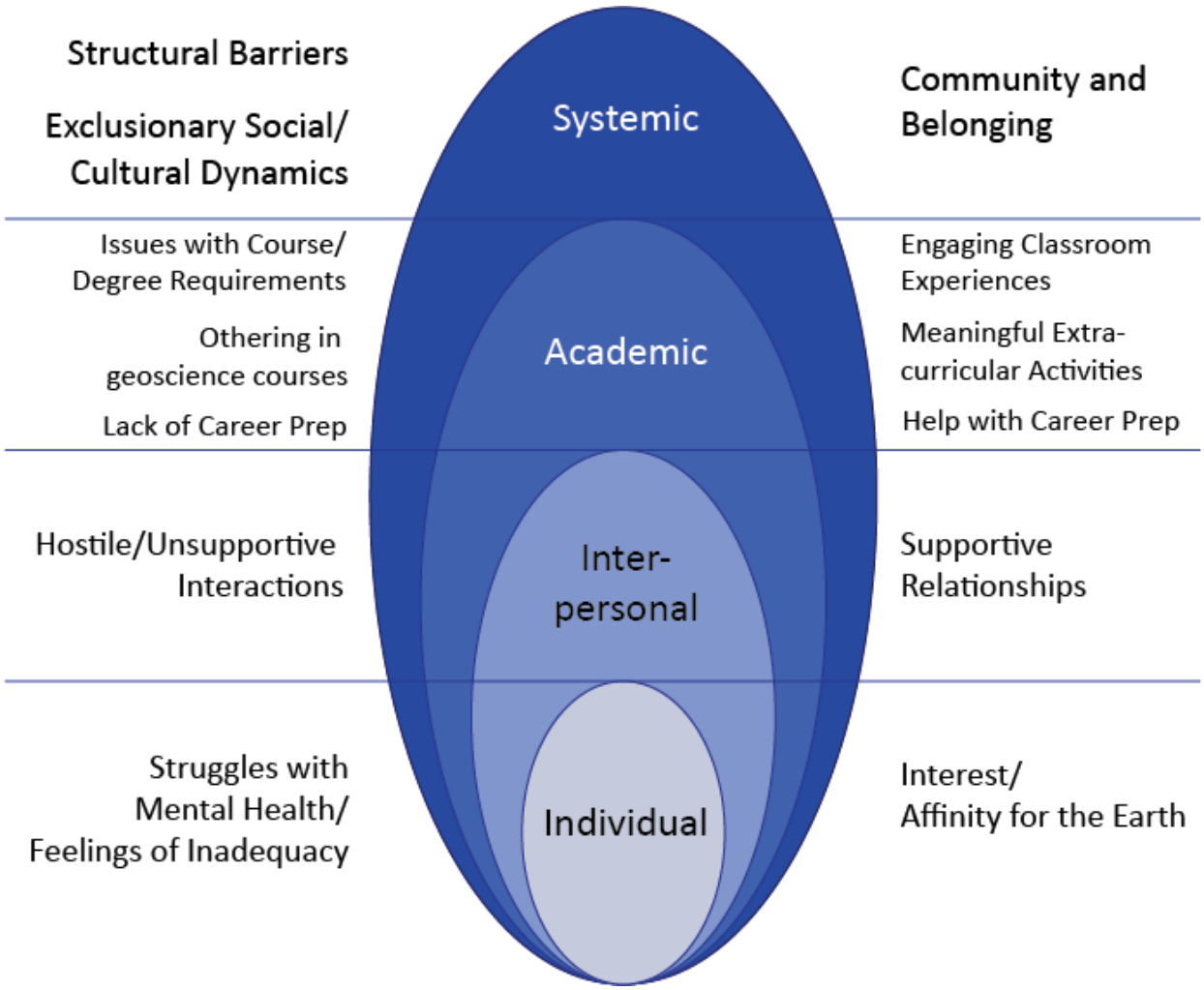


Figure 8. Diagram of themes on individual, interpersonal, academic, and systemic levels. Themes on the left side of the figure were found to be detrimental to student success; themes on the right found to be encouraging student persistence.

Table 1. Earth, Ocean, and Atmospheric science degrees awarded from 2008-2018, in percentages by race and ethnicity. "Percentage of general population" numbers are derived from 2009-2019 demographics. Source: Women, Minorities, and Persons with Disabilities in Science and Engineering.

	Bachelor's	Master's	Doctorate	Average of all degrees	% of General Population
Hispanic or Latino	7.25	5.31	4.44	5.66	16.63
American Indian or Alaska Native	0.64	0.55	0.42	0.54	0.77
Asian	3.72	2.81	4.10	3.54	5.03
Black or African American	2.26	2.09	1.81	2.05	12.42
Native Hawaiian or Other Pacific Islander	0.16	0.11	0.07	0.11	0.14
White	80.06	81.45	80.34	80.62	63.26
More than one race	3.06	2.46	1.84	2.45	1.81
BIPOC	14.03	10.87	10.84	11.91	34.99

Table 2. Results of a literature review compiling common experiences of geoscience degree programs that are linked to the formation of students' geoscience identity.

Common experiences influencing geoscience identity	**Example studies**
Learning use of tools, equipment, and other material resources	Perin et al., 2020
Research experience (non-course-based)	Cooper et al., 2019; Kortz et al., 2020
Course-based research experience	Kortz and van der Hoeven Kraft, 2016
Place-based geoscience courses	DeFelice et al., 2019, Semken et al., 2017
Coursework incorporating cultural relevance and/or Indigenous knowledge	Dublin, et al., 2018, Semken, 2018
Faculty mentors and role models	Baber et al., 2010; Levine et al., 2007; Stokes et al., 2015
Field experiences	Streule and Craig, 2018; Mogk and Goodwin, 2012; LaDue and Pacheco, 2013
Gaining knowledge of geoscience careers	Baber et al., 2010; Levine et al., 2007; Stokes et al., 2015
Receiving support from family and peers	Levine et al., 2007; Baber et al., 2010
Feeling a sense of belonging; relating to geoscience culture	Levine et al., 2007; Stokes et al., 2015; Dutt, 2019
Microaggressions (small instances of indirect, subtle, or unintentional discrimination)	Dutt, 2019; Marín-Spiotta et al., 2020; Giles et al., 2020
Seeing oneself represented in geoscience faculty and staff	Baber et al., 2010; Dutt, 2019
Macroaggressions (large scale or overt discrimination)	Dutt, 2019; Marín-Spiotta et al., 2020; Giles et al., 2020
Connections with Earth	LaDue and Pacheco, 2013; Levine et al, 2007; Stokes et al., 2015

Table 3. Descriptive statistics for geoscience identity survey results, divided by survey section.

Section 1: Maximum possible scores in geoscience identity measures are as follows: total identity: 75; recognition: 45; performance/competence: 30.

Section 1: Geoscience Identity			
	n	**Mean Geoscience Identity Score**	**SD**
Total Geoscience Identity Score			
All responses	139	58.4	6.54
BIPOC (all gender identities)	64	57.4	6.64
White (all gender identities)	75	59.8	6.22
BIPOC, Female and Non-Binary	37	58.0	7.44
BIPOC, Male	27	55.8	4.96
White, Female and Non-Binary	51	59.1	6.85
White, Male	24	60.6	5.12
Recognition			
All responses	139	34.3	4.59
BIPOC (all gender identities)	64	33.9	5.10
White (all gender identities)	75	35.1	4.21
BIPOC, Female and Non-Binary	37	34.3	5.53
BIPOC, Male	27	32.9	4.00
White, Female and Non-Binary	51	35.0	4.63
White, Male	24	34.6	3.26
Performance/Competence			
All responses	139	24.0	3.16
BIPOC (all gender identities)	64	23.5	2.75
White (all gender identities)	75	24.7	3.30
BIPOC, Female and Non-Binary	37	23.7	3.13
BIPOC, Male	27	23.0	2.18
White, Female and Non-Binary	51	24.1	3.36
White, Male	24	25.7	2.99

Section 2: Ratings of common experiences are as follows: -2 = had a strong negative impact; -1 = had a negative impact; 0 = had neither a positive nor a negative impact; 1 = had a positive impact; 2 = had a strong positive impact. A mean rating of 1.5, for example, indicates a rating falling equally between 'had a positive impact' and 'had a strong positive impact'.

Section 2: Common Experiences Influencing Geoscience Identity			
Number of responses: 139			
Factor influencing geoscience identity	**Mean Rating**	**SD**	
Learning use of tools, equipment, and other material resources	1.57	0.73	
Research experience (non-course-based)	1.49	0.68	
Course-based research experience	1.34	0.73	
Place-based geoscience courses	1.45	0.82	
Coursework incorporating cultural relevance and/or Indigenous knowledge	1.40	0.79	
Faculty mentors and role models	0.90	0.91	
Field experiences	1.51	0.86	
Gaining knowledge of geoscience careers	1.29	0.87	
Receiving support from family and peers	1.21	0.85	
Feeling a sense of belonging; relating to geoscience culture	1.12	0.97	
Connections with Earth	1.50	0.74	
Seeing oneself represented in geoscience faculty and staff	1.05	0.96	
Microaggressions (small instances of indirect, subtle, or unintentional discrimination)	-0.68	0.89	
Macroaggressions (large scale or overt discrimination)	-0.53	0.97	

Section 3: Demographics of students responding to open-ended questions. Note: survey respondents were allowed to select more than one multiple-choice response for demographic questions, so the total of each demographic category answering open-ended questions section may not equal the total number of respondents.

Section 3: Open-Ended Responses			
	n		
Total	129		
Ethnicity			
Hispanic or Latino	26		
Non-Hispanic or Latino	102		
Race			
American Indian or Alaska Native	5		
Asian	16		
Black or African American	7		
More than one race	15		
Native Hawaiian or Other Pacific Islander	1		
Other/I'll type it below	8		
White	101		
Gender Identity			
Female	75		
I prefer not to say	1		
I'll type it below	3		
Intersex	1		
Male	43		
Non-binary	12		

Table 4. Convergence coding matrix including quantitative results of students' ratings of common experiences influencing geoscience identity, related qualitative themes and codes, and degree of fit between quantitative and qualitative results.

Common experience influencing geoscience identity	Mean*	SD	Group differences in ratings**	Present in qualitative findings***	Relevant themes	Relevant codes	Degree of fit****
Learning use of tools, equipment, and other material resources	1.57	0.73		+	Engaging classroom experiences, meaningful extracurricular activities	Research Experiences, Engaging geoscience course content	1
Research experience (non-course-based)	1.49	0.68		++	Meaningful extracurricular activities	Research Experiences	1
Course-based research experience	1.34	0.73		-	N/A	N/A	N/A
Place-based geoscience courses	1.45	0.82		-	N/A	N/A	N/A
Coursework incorporating cultural relevance and/or Indigenous knowledge	1.40	0.79		++	Othering in geoscience courses	Culturally relevant course content, Indigenous knowledge	3
Faculty mentors and role models	0.90	0.91		++	Supportive Relationships	Mentors, Respect from Professors, Role Models	1
Field experiences	1.51	0.86		++	Engaging classroom experiences, meaningful extracurricular activities	Field Experiences, Outdoor Experiences, Outdoors Work	1
Gaining knowledge of geoscience careers	1.29	0.87		++	Help with Career Preparation, Lack of Career Preparation	Career development activities, Geoscience internships, Geoscience job market, Knowledge of Geoscience careers, Outdoors work, salary	1

Receiving support from family and peers	1.21	0.85		++	Supportive Relationships, Hostile/Unsupportive Interactions	Family commitments, Family support, Peer support	1
Feeling a sense of belonging; relating to geoscience culture	1.12	0.97		++	Community and Belonging, Exclusionary Cultural/Social Dynamics, Structural Barriers	Cultural differences, Department culture, Geoscience culture, Sense of belonging	1
Connections with Earth	1.50	0.74	FNB BIPOC > M White*	++	Interest/Affinity for the Earth	Connection/love of nature, Protecting the environment, Interest	1
Seeing oneself represented in geoscience faculty and staff	1.05	0.96	FNB BIPOC > M White** FNB White > M White***	++	Community and Belonging, Structural Barriers	Representation in faculty and staff, Sense of belonging	1
Micro-aggressions (small instances of indirect, subtle, or unintentional discrimination)	-0.68	0.89	FNB BIPOC < M White**	++	Struggles with mental health/feelings of inadequacy, Hostile/Unsupportive Interactions	Microaggressions; Encounters with: sexism, ageism, racism, homophobia	1
Macro-aggressions (large scale or overt discrimination)	-0.53	0.97	FNB BIPOC, FNB White < M White*	++	Struggles with mental health/feelings of inadequacy, Exclusionary Cultural/Social Dynamics	Encounters with: sexism, ageism, racism, homophobia	1

* The mean score of each common experience is based on a Likert-type scale. Ratings are as follows: -2 = had a strong negative impact; -1 = had a negative impact; 0 = had neither a positive nor a negative impact; 1 = had a positive impact; 2 = had a strong positive impact. A mean rating of 1.5, for example, indicates a rating falling equally between 'had a positive impact' and 'had a strong positive impact'.

** FNB = Female and Non-Binary; M = Male; BIPOC = Black, Indigenous, and People of Color

***If exact information relating to a factor was identified in qualitative results, a ++ was used. If related or supporting information was found, a + was used. If no related information was found, a – was used.

**** In describing degree of fit between qualitative and quantitative results, a 1 indicates confirmation between results, a 2 indicates expansion (some overlap, with separate yet complementary findings), and a 3 indicates discordance (contradictions between results).

Table 5. All themes identified in qualitative analysis, with codes attributed to each theme, and emblematic quotes from survey responses illustrating the range within each theme.

Codes Included	Code Definition	Example
Interest/ Affinity for the Earth		
Connection to, desire to study or protect the Earth/nature		
Interest	Interest, appreciation, or love of the subject matter of geoscience	"I love the subject material"; "I realized how much I loved Earth science"; "I love rocks"
Connection/love of nature	Feeling connected to the Earth; appreciating or loving nature	"My love of mountains"; "I feel connected to the Earth"
Helping others	Desire or drive to help other people and/or make a positive impact for others in the world.	"Helping people with geological hazards"
Protecting the environment	Desire to protect the environment, 'fight climate change' or 'save the world'	"Want to save the planet"; "I want to help the Earth"
Struggles with mental health/feelings of inadequacy		
Issues with mental health, especially low confidence or 'imposter syndrome'		
Personal characteristics	Mention of personal reasons or personal issues that do not fall into 'mental health', 'burnout', 'interest', or other categories.	"[Considered leaving the major] due to personal reasons"
Burnout	Burnout	"coming close to burnout"
Imposter syndrome	Specific feeling of not being capable or worthy while peers are; feeling like an imposter, or someone who is 'faking' it	"I get imposter syndrome that I don't really know enough to work"
Mental health	State of one's mental health	"I've considered dropping out of school multiple times due to poor mental health"
Geoscience self-efficacy	Belief in one's ability to succeed in geoscience or geoscience courses	"Have had feelings that I'm not good enough to succeed in geology"; "I thought about switching to photography, it would have been something easier"; Sometimes I felt too stupid in classes"
Math self-efficacy	belief in one's ability to succeed in math or math courses	"I couldn't seem to do well in calculus"
Supportive Relationships		
Supportive relationships with friends, family, and professors		

Mentors	Mentors in geoscience. Includes 1-on-1 relationships with faculty and staff, other students, or professionals.	"after talking with Professor [redacted], I changed my mind"; "My biggest influences were kind people who took time to conduct research with me and professors who were passionate about their jobs."
Role models	Geoscientists that students can look up to. Includes geoscience faculty and staff, public figures, or geoscientists with a personal connection to the student.	"I saw Robert Ballard speak when I was young and that inspired me to become a marine geologist"
Peer support	Relationships, friendships, and support from peers in geoscience	"I've felt very welcomed by my peers"; "I have had the opportunity to meet some really awesome friends"
Hostile/Unsupportive Interactions		
Comments, jokes, or other brief interactions rooted in prejudice; strained relationships		
Respect from professors (negative)	Feeling respected or recognized by course instructors or other professors	"I feel like my professors don't respect me for my knowledge"
Microaggressions	Discriminatory remarks, comments, jokes, etc. made in everyday interactions	"Experienced microaggressions as a member of the Latino community", "I experienced several comments from faculty about whether or not I will pursue teaching"
Encounters with racism/sexism/ageism/homophobia	Discrimination based on race/ethnicity, gender identity, age, or sexual orientation	"I felt discriminated against due to my age", "Experienced some microaggressions as a gay man", "I could not let a man or unfortunate situations take away what I feel so passionate about"
Family commitments (negative)	Commitments to family (includes child care)	"overwhelmed with school course load and family life"
Family support (negative)	Lack of support (financial, emotional, etc.) from family	"My family didn't support my dreams to be a geoscientist."; "I did consider leaving because my husband lives on the other side of the country"
Help with Career Preparation		
Gaining understanding of and experience in the geoscience workforce		
Career development activities (positive)	Networking, workshops, or job-training activities. For specific mentions of internships, use "geoscience internships" instead.	"It has allowed me to network with other geoscientists"

Geoscience internships	Internships (paid or unpaid) within field of geoscience	"I got the opportunity to try different aspects of geoscience through internships. So far, I had done hydrogeology and micropaleontology."
Geoscience job market	Perception of the state of the geoscience job market	"job growth is good" "[will pursue a career in geoscience] if the economy does not tank"
Knowledge of geoscience careers (positive)	Knowledge or awareness of various potential geoscience careers or career paths	"career opportunities - when I turned to geophysics, I felt I had multiple possible paths"; "interest in the environment that can translate into employment"
Salary (positive)	Perception of salary in geoscience careers	"the job growth is good, and the pay is good"; "money in water, mineral, and energy sectors"
Outdoors work (positive)	Field-based geoscience jobs. Includes any references to jobs or careers that require working outside.	"I want to work outdoors, I love science, and want to save the planet"; I always loved natural science, and I wanted a job that didn't keep me in a lab all day"
Lack of Career Preparation		
Lack of understanding or an unfavorable outlook of the geoscience workforce		
Geoscience job market	Perception of the state of the geoscience job market	"job hunting is difficult"; "I was worried about careers"
Knowledge of geoscience careers	Knowledge or awareness of various potential geoscience careers or career paths	"didn't know what I will do with the degree"; "There were times when I considered switching from geoscience to geology since I wasn't sure if I wanted to pursue a career in science education."; "I think more access to possible career options and job descriptions would be helpful"
Salary	Perception of salary in geoscience careers	"[Considered leaving] for a more lucrative career"
Outdoors work (negative)	Field-based geoscience jobs. Includes any references to jobs or careers that require working outside.	"I am concerned that I am not the best fit for field work and therefore cannot complete tasks required for professional jobs."; "I have very little field experience and worry about how I will perform as a geoscientist after receiving my degree"
Engaging classroom experiences		
Positive and encouraging experiences in geoscience courses		

Engaging geoscience course content	Course content that is interesting and engaging.	"We did a lab with the stream table that I loved. I find studying the Earth to be very personally engaging"
Course selection	Selection of available geoscience courses; choosing to take geoscience courses	"When taking my general education classes, I took a few classes that I greatly enjoyed and they made me consider switching majors"
Introductory Geoscience	Introductory geoscience courses, such as Geology 101	"My 101 prof was hyped about class and that got me hyped about class"
Effective instruction (positive)	Engaging or effective instruction by faculty in geoscience courses.	“My teacher in HS would make it interesting to learn and I became fascinated with the subject”
Field experiences (positive)	Field experiences associated with classes. Includes field trips, field camp or other field-based classes, and field work for independent research (e.g. senior thesis)	"Field experiences and research outside of courses solidified my identity as a geoscientist and student of the earth"
Othering in geoscience courses		
Being made to feel like an outsider in classes based on course content, or instructor/classmate behavior		
Indigenous knowledge (negative)	Lack of recognition, inclusion, or valuing of Indigenous knowledge. Includes Traditional Ecological Knowledge and/or Indigenous culture in course content.	"Sometimes I see people pull up pictures of places... that are from my reservation and they don't even mention how my people have 20,000+ years of history in the area"
Effective instruction (negative)	Harmful, exclusionary, or ineffective instruction by faculty in geoscience courses.	"The professor made the experience awful"; "I had a professor who assumed we were all stupid and just gave up on us"
Field experiences (negative)	Bad field experiences associated with classes. Includes field trips, field camp or other field-based classes, and field work for independent research (e.g. senior thesis)	"Only considered leaving during the field structural class"; “I felt incompetent in the field. The projects after the fieldwork also brought me a lot of stress”
Issues with course/degree requirements		
Problems with requirements of courses or degree programs		
Required STEM courses (negative)	Non-geoscience STEM courses required for major (e.g. physics)	"Physics rocked my GPA"; "Gen-Ed math and physics are meant for engineers at my university, so none of the things I learned was fully relevant"
Required geoscience courses (negative)	Mentions of geoscience courses required for the major	"Mineralogy. That should answer it"

Awareness of geoscience (negative)	Awareness or knowledge of geoscience as a field, major, or potential career path	"I thought that to study things related to space I had to be i physics"; "Being confused on what geology or geoscience even was"
Department academics (negative)	Quality of geoscience courses, availability of geoscience courses offered	"program is too rigid"; "sometimes it's hard to enroll because there [aren't] professors to teach the subjects"
Meaningful extracurricular activities		
Positive and encouraging experiences in clubs, research outside of courses, etc.		
Extracurricular activities	Volunteering, clubs, or other structured activities relating to geoscience.	"The geology club has helped me a lot in making connections to both my peers and faculty"
Lab/reading groups	Lab groups or reading groups in geoscience departments	"Lab groups where we read and analyzed scientific papers"
Teaching experiences	Opportunities to teach geoscience as a teaching assistant or other position	"being a TA"; "plan on teaching Earth science"
Research experiences	Research experiences with faculty as part of courses, summer experiences, senior theses, or not-specified	"My advisor has given me the opportunity to work on my own research with him and write a thesis"
Outdoor experiences	Time spent outdoors. Includes hiking, vacations, or other outdoor recreational activities.	"Love the outdoors. Love hiking"
Travel	Ability or opportunity to travel for geoscience-related activities, courses, or jobs	"I enjoyed taking classes and participating in research experiences that allowed me to travel"
Exclusionary Cultural/Social Dynamics		
Social environments and overall culture in geoscience departments (or within the field in general) that are exclusionary		
Department culture (negative)	Culture, social norms, and community within the student's geoscience department.	“Our building does not have a women’s bathroom on the second floor… women didn’t do research in labs, so they just never added a bathroom. To this day, 50 years later, there is still no bathroom, no matter how much we advocate for one”.
Geoscience culture (negative)	Culture and community within the field of geoscience.	"I didn't feel like I belonged because I didn't want to study traditional geology and go into oil, resource extraction, etc."; “Everything is really disconnected, and I definitely feel alone most times in geoscience… I know it takes presences like mine to change that, but it’s hard”

Sense of belonging (negative)	Feeling of fitting in or belonging in one's department or in the field of geoscience in general	"I feel like I don't fit in with my geoscience peers"; "I wasn't finding myself in this major"; "I do not enjoy being out in the field, while most of my peers do. This made me feel like maybe I did not belong in the field of geosciences."
Cultural differences	Having a cultural background different to peers, faculty, or staff; differences in cultural norms or expectations among members of a geoscience department or community.	"I find very few people with my cultural background."; "I am from Hawai'i...but a lot of my classmates are from the mainland, so the cultural differences are noticeable"
Encounters with racism/sexism/ageism/homophobia	Discrimination based on race/ethnicity, gender identity, age, or sexual orientation	"I felt discriminated against due to my age", "Experienced some microaggressions as a gay man", "I could not let a man or unfortunate situations take away what I feel so passionate about"
Community and Belonging		
Feeling of community and belonging in geoscience departments (or within the field in general)		
Department culture (positive)	Culture, social norms, and community within the student's geoscience department. For mentions of culture or social norms within the broader context of the field of geoscience, use "geoscience culture" instead.	"I feel so at home with the faculty and with my peers"; "Team-building"; "[the department] is fairly small so it is easy to get to know other classmates and professors"
Geoscience culture (positive)	Culture and community within the field of geoscience. For mentions of specific community or culture within a student's geoscience department, use "department culture" instead.	"As a white male in the geosciences, I (unsurprisingly) haven't experienced any discrimination based on who I am"
Sense of belonging (positive)	Feeling of fitting in or belonging in one's department or in the field of geoscience in general	“So much community in the geo group. It’s awesome. And it doesn’t feel competitive”; “The faculty and the environment they cultivate is amazing”; “I feel so at home with the faculty and with my peers"
Structural Barriers		
Barriers to student success existing at the institutional or societal level		

Covid-19 impacts	Educational impacts related to Covid-19 pandemic. See also: remote modality.	"With the pandemic I was not able to attend field camp in person so that puts me at a disadvantage in a way."
Remote modality	Online classes. Includes asynchronous or synchronous online classes.	"Especially with online courses I ended up needed to retake a few core classes the next year."
Representation in faculty and staff (negative)	Seeing oneself represented in faculty or staff	"There was no representation in my school as far as I felt"; "I would have enjoyed having more women to look up to"
Affordability (negative)	Ability to afford tuition, course fees, or other costs associated with geoscience degree	"I couldn't afford the field camp"
Department funding (negative)	Department funding available for students, lab equipment, research instruments, or other.	"My professors are all incredible but lack funding and recognition from the school"
Physical accessibility (negative)	Physical accessibility of spaces associated with geoscience courses or degree program	"I am not able to go on long hikes due to chronic back and knee pain and would constantly fall behind during my field classes"

Table 6. Content analysis of qualitative results. Percentages of responses relating to each theme are shown by race/ethnicity demographics. For example, Hispanic or Latino respondents made up 20% of the total survey population and were 26% of survey respondents who considered leaving the major.

		Ethnicity		Race						
		Hispanic or Latino (n = 26)	**Non-Hispanic or Latino (n = 102)**	**American Indian or Alaska Native (n = 5)**	**Asian (n = 16)**	**Black or African American (n = 7)**	**More than one race (n = 15)**	**Native Hawaiian or Pacific Islander (n = 1)**	**Other (n = 8)**	**White (n = 101)**
% of total respondents		**20**	**80**	**3**	**11**	**5**	**10**	**1**	**5**	**66**
										Percentage of responses pertaining to each theme by race/ethnicity group:
Who considered leaving the major?		26	75	6	12	5	12	2	6	57
Themes (Individual level)	Interest/ Affinity for Earth	23	77	3	11	5	12	1	5	65
	Struggles with mental health/ feelings of inadequacy	14	86	3	15	6	15	3	9	50
Themes (Interpersonal level)	Supportive relationships	12	88	4	8	0	12	4	4	68
	Hostile/ unsupportive interac-tions	8	92	5	11	0	16	5	11	53
Themes (Academic level)	Help with career preparation	11	89	9	9	9	9	0	0	65
	Lack of career preparation	0	100	8	8	8	8	0	0	67

	Engaging classroom experiences	24	76	0	7	0	13	0	17	63
	Othering in geoscience courses	15	85	11	6	0	11	0	11	61
	Meaningful extracurriculars	18	82	4	4	0	12	0	4	77
	Issues with course/ degree requirements	29	71	0	19	5	19	5	5	48
Themes (Systemic level)	Exclusionary social/ cultural dynamics	19	81	4	12	0	16	4	8	56
	Community & belonging	0	100	0	7	0	7	7	0	80
	Structural barriers	19	81	6	17	6	14	0	11	46

Appendices

Appendix A

Geoscience Identity Survey.

Section I

Please rate how much you agree or disagree with the following statements. We use the term "geoscientist" to refer to any type of scientist within the broad field of geosciences: geologist, geophysicist, geochemist, geomorphologist, and so on.

Matrix response options:
1 = Strongly disagree
2 = Disagree
3 = Neither Agree nor Disagree
4 = Agree
5 = Strongly Agree

Geoscience Identity

Recognition
I identify as a geoscientist
I am comfortable identifying myself as a geoscientist
My field of study helps me identify as a geoscientist
My faculty members recognize me as a geoscientist
My peers recognize me as a geoscientist
My family and friends recognize me as a geoscientist
It is not important to me that others see me as a geoscientist
Seeing other people who look like me within my field reinforces my geoscience identity
Doing geoscience is not important to who I am

Performance/Competence
I am confident that I can understand geoscience in class
I am confident that I can understand geoscience outside of class
I can do well on exams and projects in geoscience
I do not understand concepts I have studied in geoscience
Others ask me for help in geoscience
I cannot overcome setbacks in geoscience

(adapted from Godwin et al., 2016; Williams and George, 2014)

Using and Doing Science

My knowledge and skills will allow me to help others
My knowledge and skills will allow me to contribute to social issues that are important to me

I do not enjoy conducting research (reverse)
I have to work harder than my peers to be recognized as a geoscientist due to my race or ethnicity
I have to work harder than my peers to be recognized as a geoscientist due to my gender

(adapted from Williams and George, 2014)

If you would like to discuss any of your answers, you may do so below:

Section II

If any of the following have had an influence (positive or negative) on your ability to identify as a geoscientist, please rate their impact. You may select "N/A" for any you did not experience.

Matrix response options:
-2 = Had a strong negative impact
-1 = Had a negative impact
0 = Had neither a positive nor negative impact
1 = Had a positive impact
2 = Had a strong positive impact
N/A = Not Applicable/ did not experience this

Faculty mentors and role models
Learning use of tools, equipment, and other material resources
Research projects in class
Research experience outside of regular classes
Place-based geoscience courses
Coursework incorporating cultural relevance and/or Indigenous knowledge
Field experiences
Gaining knowledge about geoscience careers
Receiving support from family and peers
Feeling a sense of belonging; relating to geoscience culture
Feeling connected to the Earth
Seeing oneself represented in geoscience faculty and staff
Microaggressions (small instances of indirect, subtle, or unintentional discrimination)
Macroaggressions (large scale or overt discrimination)

(For citations, see Table 2)

Section III

1. What was the main reason you chose your geoscience major?
2. Did you ever consider leaving your geoscience major? If so, why?
3. Did you switch from a different major into your geoscience major? If so, what was your original major and why did you choose geoscience?
4. Are you planning on going into a career in the geosciences after you graduate? Please explain.

5. Were there any important aspects of your experience as a geoscience major that were not listed above? If so, please describe them and the effect they had on your identity as a geoscientist.

Section IV

Which of the following most accurately describes you?
You may choose more than one.
Response options:
Non-binary
Female
Male
Intersex
I prefer not to say
I'll type it below

You may also state your gender identity in your own words below:
What is your ethnicity?
Response options:
Hispanic or Latino
Non-Hispanic or Latino

What is your racial background?
Response options:
American Indian or Alaska Native
Asian
Black or African American
Native Hawaiian or Other Pacific Islander
White
More than one race
Other/I'll type it below

You may also state your racial/ethnic background in your own words below:
If there are any other aspects of your identity you would like to share, please add it below:

Appendix B

Survey Recruitment Language.

The following IRB-approved language was sent to geology student listservs at 99 U.S. universities.

Are you a senior (4th year or above) undergraduate student in the geosciences?

Please participate in this 8-10 minute online research survey to assess the experiences of undergraduate geoscience majors and their ability to identify as geoscientists. This survey is being conducted as part of a study within the Geology Department at Western Washington University by graduate student Willa Rowan and is advised by Dr. Robyn Dahl. You must be 18 years or older to participate.

Participants who complete the survey may enter a raffle for one of several $50 Amazon e-gift cards in appreciation of their time.

Survey link: https://wwu.az1.qualtrics.com/jfe/form/SV_06xWFIje3o2M1nw

This research has undergone IRB review at Western Washington University under number 4633EX22.

Appendix C

Code manual used for thematic analysis.

Thematic Analysis		
Code Name	**Definition**	**Example**
Awareness of geoscience	Awareness or knowledge of geoscience as a field, major, or potential career path	"I thought that to study things related to space I had to be i physics"; "Being confused on what geology or geoscience even was"
Burnout	Burnout	"coming close to burnout"
Career development activities	Networking, workshops, or job-training activities. For specific mentions of internships, use "geoscience internships" instead.	"It has allowed me to network with other geoscientists"
Connection/ love of nature	Feeling connected to the Earth; appreciating or loving nature	"My love of mountains"; "I feel connected to the Earth"
Course selection	Selection of available geoscience courses; choosing to take geoscience courses	"When taking my general education classes, I took a few classes that I greatly enjoyed and they made me consider switching majors"
Covid-19 impacts	Educational impacts related to Covid-19 pandemic. See also: remote modality.	"With the pandemic I was not able to attend field camp in person so that puts me at a disadvantage in a way."
Cultural differences	Having a cultural background different to peers, faculty, or staff; differences in cultural norms or expectations among members of a geoscience department or community. For specific mentions of social or cultural values related to one's background, use "ethnic cultural values and socialization" instead.	"As a native american trans person in geoscience, I find very few people with my cultural background."; "I am from Hawai'i and attend UHM, but a lot of my classmates are from the mainland, so the cultural differences are noticeable"
Culturally relevant course content	Recognition or inclusion of culturally relevant material in courses. For course material specifically based in Indigenous knowledge,	"When I do hear people talk about national parks and land-based knowledge they talk about it in a very clinical way"

	use "Indigenous knowledge" instead.	
Department academics	Quality of geoscience courses, availability of geoscience courses offered	"program is too rigid"; "sometimes it's hard to enroll because there [aren't] professors to teach the subjects"
Department culture	Culture, social norms, and community within the student's geoscience department. For mentions of culture or social norms within the broader context of the field of geoscience, use "geoscience culture" instead.	"I feel so at home with the faculty and with my peers"; "Team-building"; "[the department] is fairly small so it is easy to get to know other classmates and professors"
Department funding	Department funding available for students, lab equipment, research instruments, or other.	"My professors are all incredible but lack funding and recognition from the school"
Effective instruction	Engaging or effective instruction by faculty in geoscience courses. For mentions of engaging course content that does not have to do with the instructor's teaching, use "engaging geoscience course content" instead.	"My 101 prof was hyped about class and that got me hyped about class"
Encounters with ageism	Discrimination based on age. Includes differential treatment, microaggressions, jokes, comments, or expressing prejudiced opinions.	"I felt discriminated due to my age"
Encounters with homophobia	Discrimination based on sexual orientation. Includes differential treatment, microaggressions, jokes, comments, or expressing prejudiced opinions.	"Experienced some micro aggressions as a gay man"
Encounters with racism	Discrimination based on race/ethnicity. Includes differential treatment, microaggressions, jokes, comments, or expressing prejudiced opinions.	"I did receive micro aggressions as a member of the Latino community"

Encounters with sexism	Discrimination based on gender identity. Includes differential treatment, microaggressions, jokes, comments, or expressing prejudiced opinions.	"I could not let a man or unfortunate situations take away what I feel so passionate about."
Engaging geoscience course content	Course content that is interesting and engaging. For mentions of effective instruction or engaging delivery of course material by an instructor, use 'effective instruction' instead.	"We did a lab with the stream table that I loved"
Ethnic cultural values and socialization	Cultural and social values based in one's ethnic background or family heritage. For mentions of one's cultural background (usually as it relates to others') that are not specifically about cultural or social values, use the more general "cultural differences" instead.	"One time, when looking at Walla Walla, someone in my class even said "what a dumb name, who named that?" and I had to raise my hand to say "well, WÃele is the word for river in our plateau langauges, that's where this comes from. It means full of rivers." And the class just went silent."
Extracurricular activities	Volunteering, clubs, or other structured activities relating to geoscience. For personal time spent exploring geoscience, consider using "outdoor experiences" instead.	"The geology club has helped me a lot in making connections to both my peers and faculty"
Family commitments	Commitments to family (includes child care)	"overwhelmed with school course load and family life"
Family support	Receiving support (financial, emotional, etc.) from family	"My family didn't support my dreams to be a geoscientist."; "I did consider leaving because my husband lives on the other side of the country"
Field experiences	Field experiences associated with classes. Includes field trips, field camp or other field-based classes, and field work for independent research (e.g. senior thesis)	"Field experiences and research outside of courses solidified my identity as a geoscientist and student of the earth"; "Only considered leaving during the field structural class"
Fiscal abilities	Ability to afford tuition, course fees, or other costs	"I couldn't afford the field camp"

	associated with geoscience degree	
Geoscience culture	Culture and community within the field of geoscience. For mentions of specific community or culture within a student's geoscience department, use "department culture" instead.	"I didn't feel like I belonged because I didn't want to study traditional geology and go into oil, resource extraction, etc."
Geoscience internships	Internships (paid or unpaid) within field of geoscience	"I got the opportunity to try different aspects of geoscience through internships. So far, I had done hydrogeology and micropaleontology."
Geoscience job market	Perception of the state of the geoscience job market	"job hunting is difficult"; "job growth is good" "[will pursue a career in geoscience] if the economy does not tank"
Geoscience self-efficacy	belief in one's ability to succeed in geoscience or geoscience courses	"Have had feelings that I'm not good enough to succeed in geology"; "I thought about switching to photography, it would have been something easier"; Sometimes I felt too stupid in classes"
Helping others	Desire or drive to help other people and/or make a positive impact for others in the world.	"Helping people with geological hazards"
Imposter syndrome	Specific feeling of not being capable or worthy while peers are; feeling like an imposter, or someone who is 'faking' it	"I get imposter syndrome that I don't really know enough to work"
Indigenous knowledge	Recognition, inclusion, and valuing of Indigenous knowledge. Includes Traditional Ecological Knowledge and/or Indigenous culture in course content.	"Sometimes I see people pull up pictures of places... that are from my reservation and they don't even mention how my people have 20,000+ years of history in the area"
Interest	interest, appreciation, or love of the subject matter of geoscience	"I love the subject material"; "I realized how much I loved Earth science"; "I love rocks"
Introductory Geoscience	Introductory geoscience courses, such as Geology 101	"My 101 prof was hyped about class and that got me hyped about class"

Knowledge of geoscience careers	Knowledge or awareness of various potential geoscience careers or career paths	"didn't know what I will do with the degree"; "There were times when I considered switching from geoscience to geology since I wasn't sure if I wanted to pursue a career in science education."; "I think more access to possible career options and job descriptions would be helpful"
Lab/ reading groups	Lab groups or reading groups in geoscience departments	"Lab groups where we read and analyzed scientific papers"
Math self-efficacy	belief in one's ability to succeed in math or math courses	"I couldn't seem to do well in calculus"
Mental health	State of one's mental health	"I've considered dropping out of school multiple times due to poor mental health"
Mentors	Mentors in geoscience. Includes 1-on-1 relationships with faculty and staff, other students, or professionals.	"after talking with Professor [redacted], I changed my mind"; "My biggest influences were kind people who took time to conduct research with me and professors who were passionate about their jobs."; "I decided to go into geology per my professor's suggestion"
Microaggressions	Discriminatory remarks, comments, jokes, etc. made in everyday interactions	"Experienced microaggressions as a member of the Latino community", "I experienced several comments from faculty about whether or not I will pursue teaching"
Outdoor experiences	Time spent outdoors. Includes hiking, vacations, or other outdoor recreational activities. For field experiences relating to geoscience courses, use "field experiences". For outdoors-related jobs, use "outdoors work".	"Love the outdoors. Love hiking"
Outdoors work	Field-based geoscience jobs. Includes any references to jobs or careers that require working outside. For mentions of field-based research or coursework taken for credit (sometimes still called 'field work' but is in the context of school), use "field experiences" instead.	"I am concerned that I am not the best fit for field work and therefore cannot complete tasks required for professional jobs."; "I have very little field experience and worry about how I will perform as a geoscientist after receiving my degree"
Peer support	Relationships, friendships, and support from peers in geoscience	"I've felt very welcomed by my peers"; "I have had the opportunity to meet some really awesome friends"

Personal characteristics	Mention of personal reasons or personal issues that cannot be resolved by 'mental health', 'burnout', 'interest', or other categories. Should only be used as a last resort.	"due to personal reasons"
Physical accessibility	Physical accessibility of spaces associated with geoscience courses or degree program	"I am not able to go on long hikes due to chronic back and knee pain and would constantly fall behind during my field classes"
Protecting the environment	Desire to protect the environment, 'fight climate change' or 'save the world'	"Want to save the planet"; "I want to help the Earth"
Remote modality	Online classes. Includes asynchronous or synchronous online classes.	"especially with online courses i ended up needed to retake a few core classes the next year."
Representation in faculty and staff	Seeing oneself represented in faculty or staff	"There was no representation in my school as far as I felt"
Required geoscience courses	Mentions of geoscience courses required for the major	"Mineralogy. That should answer it"
Required STEM courses	Non-geoscience STEM courses required for major (e.g. physics)	"Physics rocked my GPA"; "Gen-Ed math and physics are meant for engineers at my university, so none of the things I learned was fully relevant"
Research experiences	Research experiences with faculty as part of courses, summer experiences, senior theses, or not-specified	"My advisor has given me the opportunity to work on my own research with him and write a thesis"
Respect from professors	Feeling respected or recognized by course instructors or other professors in the department	"I feel like my professors don't respect me for my knowledge"
Role models	Geoscientists that students can look up to. Includes geoscience faculty and staff, public figures, or geoscientists with a personal connection to the student.	"I would have enjoyed having more women to look up to"; "I saw Robert Ballard speak when I was young and that inspired me to become a marine geologist"
Salary	Perception of salary in geoscience careers	"[Considered leaving] for a more lucrative career"

Sense of belonging	Feeling of fitting in or belonging in one's department or in the field of geoscience in general	"I feel like I don't fit in with my geoscience peers"; "I wasn't finding myself in this major"; "I do not enjoy being out in the feel, while most of my peers do. This made me feel like maybe I did not belong in the field of geosciences."
Teaching experiences	Opportunities to teach geoscience as a teaching assistant or other position	"plan on teaching Earth science"
Travel	Ability or opportunity to travel for geoscience-related activities, courses, or jobs	"I enjoyed taking classes and participating in research experiences that allowed me to travel"
Sentiment Analysis		
Code Name	**Definition**	**Example**
Positive	Relating to positive/beneficial/happy/good experiences or sentiments, regardless of phrasing of response. For example, to the question "did you ever consider leaving your geoscience major?" the answer "no" would be coded with a positive sentiment.	"No, I've never considered leaving. I feel so at home with the faculty and with my peers, and I love the subject material."
Negative	Relating to negative/detrimental/unsatisfactory/bad experiences or sentiments, regardless of phrasing of response. For example, to the question "did you ever consider leaving your geoscience major?" the answer "yes" would be coded with a negative sentiment.	"With the pandemic I was not able to attend field camp in person so that puts me at a disadvantage in a way."
Note: every time a thematic code is applied to a quotation, a sentiment code of 'positive' or 'negative' should accompany the thematic code.		