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Choosing the Geoscience Major: Important Factors, Race/Ethnicity, and Gender

Philip J. Stokes,^{1,a} Roger Levine,² and Karl W. Flessa¹

ABSTRACT

Geoscience faces dual recruiting challenges: a pending workforce shortage and a lack of diversity. Already suffering from low visibility, geoscience does not resemble the makeup of the general population in terms of either race/ethnicity or gender and is among the least diverse of all science, technology, engineering, and math fields in the U.S. Many studies discuss recruiting and diversity issues in science and math, but only a small number consider—and address quantitatively—barriers in geoscience. We interviewed 31 current and former geoscience majors (18 women, 13 men; 8 Hispanics, 21 whites) at a large university in the southwestern U.S. to collect 926 “critical incidents,” or experiences that affected choice of major. These critical incidents were classified, sorted, and analyzed by race/ethnicity and gender. We found that positive experiences in introductory courses, supportive family members, personal characteristics that meshed with geoscience, and outstanding field experiences were the most commonly reported factors influencing the choice of a geoscience major. Though our sample was not large, we interpret these factors as crucial tools for improving recruitment and retention. Hispanic students reported more familial factors, and more negative familial factors, than white students. Hispanic students also reported fewer informal outdoor experiences and fewer incidents involving personal factors. Men reported more critical incidents related to career and economic factors than women. Women reported more negative experiences than men in required nongeoscience courses. These findings suggest that sociocultural factors behind underrepresentation in other fields may similarly impede diversity in geoscience. Although geoscience majors share many common experiences, knowledge of subtle barriers that may exist for only Hispanic students and women in geoscience can inform recruiting, teaching, and advisement strategies. © 2015 National Association of Geoscience Teachers. [DOI: 10.5408/14-038.1]

Key words: recruiting, diversity, women, Hispanic, Latino, critical incidents

INTRODUCTION

In the long view, geoscientists are in high demand. From 2008 to 2018, it is expected that 60,000 new geoscience jobs will have been created nationwide, representing a growth rate of 23% (AGI, 2011). Yet college and university programs are not prepared to support this expansion, and a shortage of talent is predicted in the geoscience workforce. By 2022, for instance, the workforce shortage is expected to be 135,000 geoscientists (AGI, 2014a). In addressing the role of geoscientists, a National Research Council report declares that “Earth science plays a key role in the wellbeing of our nation, and many issues in its purview...are expected to grow in importance” (NRC, 2013, 1).

The field of geoscience is mostly homogeneous in terms of race/ethnicity and is among the least diverse of all science, technology, engineering, and math (STEM) fields in the U.S. Slight progress has been achieved in this area (Huntoon and Lane, 2007), but nationally, fewer than 7% of undergraduate degrees are awarded to traditionally underrepresented minorities (URMs) (NSF, 2013). Furthermore, while historical gains have been made, only 41% of undergraduate geoscience degrees are awarded to women (Larocque, 1995; Holmes and O’Connell, 2003; NRC, 2013; AGI, 2011, 2014b). In graduate programs, women earn 42% of master’s

degrees and 44% of doctoral degrees (AGI, 2014b). However, women are still underrepresented in the workforce, where they only hold 30% of geoscience jobs (AGI, 2011; NRC, 2013).

Diversity is essential to the future success of geoscience. A representative mixture of genders and cultures within an undergraduate population improves academic development and critical thinking, provides awareness of cultures and gender issues, and adds depth to the college experience (Holmes et al., 2008; Velasco and Velasco, 2010). Diversity is also a goal of federal government recruiting (NRC, 2013). The ultimate benefit of a diverse undergraduate population is a diverse workforce (Chan, 2013). Geological Society of America Past President George H. Davis, who earned his geology degrees in the 1960s, observed, “Had I been a woman or an underrepresented minority, I likely would have never found geosciences” (Davis, 2013, 14). We examine this phenomenon in the larger context of undergraduate recruitment and retention.

A SOCIOCULTURAL FOCUS

Many explanations are offered to explain the low levels of diversity in geoscience: a lack of appropriate mentors, low visibility of URMs and women, subtle biases, discrimination, cultural disconnects, and an unwillingness to acknowledge the problem (Holmes and O’Connell, 2003; Holmes et al., 2008; NRC, 2013). Lewis and Baker’s review (2010) proposed that a “cultural gap” between geology and the personal lives and identities of students could be responsible for a lack of diversity. Similarly, Semken (1999) commented that “cultural connectedness” could improve URM interest in

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geoscience education. Callahan et al. (2015) discussed how a disparity in “social capital” (i.e., the exchange of information among members of the geoscience community) could negatively affect the persistence of underrepresented groups. In their model, students who feel isolated (e.g., through negative experiences or a lack of mentors) may hesitate to trust others in the geoscience community, which subsequently erodes a sense of belonging. Though sociocultural factors are often identified as potential culprits, few studies have successfully identified these as causal barriers (O’Connell and Holmes, 2011).

Four studies closely related to our research objectives informed this work. Using evidence from place-based teaching of Earth Science topics on the Navajo Reservation, Semken concluded that geological “attributes of the places American Indians and Alaska Natives inhabit become inseparable components of their culture” (2005, 150). Semken and Freeman subsequently revealed how

“science curricula and methods that dispassionately probe and analyze places that are meaningful to these underrepresented students, or represent them in ways that are culturally inappropriate or offensive—for example, portraying planet earth as a machine or the environment as a repository for wastes—may contribute to cultural discontinuity that deters them from scientific study and careers.” (Semken and Freeman, 2008, 1044)

A traditional geology curriculum loses its effectiveness if learners are forced to create new meanings for preexisting cultural constructs. Outside of Semken’s research population of Native American students, we considered that a similar barrier could exist for other URM groups.

Munro (2009) addressed how a culturally influenced barrier may also exist for Hispanic STEM majors. Munro’s qualitative study found that family structure in Hispanic groups is a strong influence on student persistence in college and that support—or a lack thereof—can have serious implications on major selection and career decisions. In parallel, Martin (2000) showed how families strongly influenced the success of African American students in mathematics. Because math is rejected as impractical in some African American communities, Martin argued that African American students from these communities do not benefit from family-driven motivation, unlike their peers from other cultures. We hypothesize that geoscience may unwittingly discourage Hispanic and African American students if it ignores the role of families in student recruitment and persistence.

Insufficient female mentors, unhelpful advising, poor marketing of geoscience programs to women, lack of professional development opportunities, gender-based discrimination, “chilly climates” (i.e., family-unfriendly university policies), low-self confidence, unsupportive classroom environments, and a difference in career goals between men and women have been proposed as barriers to gender parity in geoscience (Larocque, 1995; Holmes and O’Connell, 2003; Libarkin and Kurdziel, 2003; Ceci and Williams, 2010; Ferreira, 2003; Hazari et al., 2013; Ceci et al., 2011; Canetto et al., 2012; Avallone et al., 2013; NRC, 2013). In addressing women already in STEM, and in comparison to men in STEM, Duberley and Cohen wrote that “women scientists feel that within the existing structures of science they do not

have access to the same forms of career capital and that their career choices are limited as a result” (2010, 195). They found that differing levels of career capital—which includes knowledge, skills, self-perceptions, and personal attributes—varies among women in different career stages and could impede persistence.

These are not the only issues that women face. Moss-Racusin et al. (2012) found that both male and female scientists have a subtle bias against female scientists. This gender bias was not part of an overt practice, yet the researchers found that female scientists were considered less competent, were less hireable, and received less mentoring than did male peers of identical experience and ability (Moss-Racusin et al., 2012). While this study is not specific to geoscience, it is possible that women in geoscience have similar experiences.

Miyake et al. (2010) studied, and countered, the stereotyped belief that men are superior to women in college physics. They noted how this stereotype, if unaddressed, caused women in physics to earn lower scores on course exams and tests. Furthermore, they argued, this stereotype was affecting the diversity within their physics major. Other biases in STEM majors have been shown to exist. In a designed experiment for undergraduate self-assessment, Correll found that men used “a more lenient standard in assessing their task competence compared to women performing at the same level” (2004, 106). Correll explained how this bias, in which self-confidence depends on gender, could lead to the attrition of women in STEM. Hill et al. (2010) further summarized how these biases, if unaddressed, lead to cognitive crutches that preclude women from pursuing STEM careers. They recommended that implicit biases in the classroom be identified and countered by instructors and students together.

CRITICAL INCIDENT TECHNIQUE

Developed by industrial and organizational psychologist John Flanagan, the critical incident technique (CIT) gathers and classifies anecdotal data from knowledgeable informants (Flanagan, 1954). The CIT was used to identify effective pilot work behaviors in the Aviation Psychology Program of the U.S. Army Air Force during World War II (Flanagan, 1954). The CIT is an interviewing technique that asks open-ended questions and gathers “critical incidents,” or self-reported experiences, from the subject’s past. The interviewer steers the questioning toward factors that causally influenced an outcome of interest (e.g., aircraft mission success or choice of major). In describing this set of procedures, Flanagan defined a critical incident as

“any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act. To be critical, an incident must occur when the purpose or intent of the act seems fairly clear to the observer and its consequences are sufficiently definite to leave little doubt concerning its effects.” (Flanagan 1954, 327)

Chell and Pittaway (1998) reviewed the assumptions needed in the CIT and similar types of ethnographic research methods. They stated, when human subjects are involved, that “data are subjective and not objective, and that

knowledge is socially constructed and not positivist” and further explained that human behavior occurs “out of a combination of the individual and their environment and that an individual’s personality is constructed from the perceptions of all actors in any given situation” (Chell and Pittaway, 1998, 25). The implication for this study is that, for respondents, reported perceptions are realities. In addition, how a respondent is reportedly perceived by others determines how the outcome of a critical incident is classified.

Edvardsson and Roos outlined how critical incidents can be collected via “personal interviews, focus group interviews, and direct or participatory observation” (2001, 253). Identifying critical incidents and their outcomes from interview or observation data is straightforward; someone broadly trained in the method can identify critical incidents in any context. Gremler (2004) explained that critical incidents are sorted either by deduction from existing theoretical models or by forming a new system based on inductive interpretation; this sorting can introduce subjectivity (Flanagan, 1954).

There are many advantages to using the CIT. Hughes (2007, 51) noted that the CIT uses a straightforward qualitative approach, has clear guidelines for data collection and analysis, relies on real human experiences and feelings, allows for practical outcomes to emerge, possesses flexibility in study design, and has been successfully used for more than 50 years in social science and educational research. CIT data are collected from the perspective of the respondent (e.g., interviewee) and allow for a range of potential responses that do not necessarily fit a predetermined schema (Gremler, 2004). As such, the CIT interview protocol uses open-ended questioning (see Supplemental File 1, available online at <http://dx.doi.org/10.5408/14-038s1>), and there are no preconceptions as to what comprises an important response. Because respondents can use their own words to answer a question, the research enables the collection of rich datasets that retain the unique perspective of each interviewee (Gremler, 2004).

One additional benefit of particular relevance to this study is that the CIT is considered unbiased regarding the cultural background of the interviewees (Gremler, 2004). Since interviewees are asked to “share their perceptions on an issue, rather than indicate their perceptions to researcher-initiated questions,” the collected data do not necessarily follow expected patterns (Gremler, 2004, 67). In practice, this flexibility allows the CIT to examine experiences and perceptions across a spectrum of respondents.

Despite these advantages, there are some drawbacks to the CIT. Gremler (2004) noted issues with reliability and validity, misinterpretations of incidents, and ambiguity with category descriptions. In addition, respondents have been found to possess a memory bias toward more recent incidents and may be unable to describe events far into the past (Hughes, 2007). For these individuals, recent critical incidents will be remembered more descriptively and more frequently than older incidents. Time further complicates the interpretation of distant experiences; reinterpretation through new insights is always a possibility (Johnstone, 1995). In these cases, the researcher may fail to appropriately classify and sort the critical incident.

Another limitation is that the CIT does not weigh the effect or meaning of incidents. Thus, “binary descriptions” of self-reported life events sometimes fail to address the

gravity of the experience (Hughes, 2007, 60). For example, a strongly negative critical incident with a substantial effect on a student’s choice of major receives the same weight—in the CIT—as a weakly negative critical incident with less effect. Thus, the CIT may overlook extremely influential experiences.

Many studies have used the CIT to help improve practices in education (e.g., Gilbert and Priest, 1997; Goodell, 2006; Levine *et al.*, 2007; Levine *et al.*, 2008; Ahluwalia, 2009; Houlton, 2010). More commonly, the CIT is used on a larger scale in the service industry to improve business practices and quality control (e.g., Chell and Pittaway, 1998; Edvardsson and Roos, 2001; Johnstone, 1995) and in the medical field to improve patient experiences (e.g., Fitzgerald *et al.*, 2008; Levine *et al.*, 2012).

Previous qualitative research has examined the choice of a geoscience major. Using the CIT, Levine *et al.* (2007) interviewed 14 geoscience faculty and professionals and identified a total of 39 factors that affected their persistence in the geoscience pipeline. However, this research was a pilot study, did not focus on choice of major, and could not investigate the effect of race/ethnicity or gender due to sample size limitations. Also using the CIT, Houlton (2010) interviewed 17 geoscience majors and created a “pathway” model to identify the specific decisions and events that led to a choice of major. This study defined two pathways: in the first, some students (i.e., “natives”) had settled on a geoscience major before college; in the second, students decided on a geoscience major later in their academic careers and only after a worthwhile experience in an introductory geoscience course. These previous studies, however, did not systematically organize and quantitatively compare the experiences of undergraduate geoscience majors. Here, we employ the CIT to quantitatively assess the experiences of students in the geoscience major. We analyze differences by race/ethnicity and by gender to guide improvement in recruitment and retention strategies and practices.

METHODS

Data Collection

We conducted critical incident interviews with 31 current and former geoscience majors: 18 women and 13 men. All study subjects self-identified as cisgender (i.e., nontransgender). We define current majors as enrolled undergraduates who, at the time of the study, had formally declared a geoscience major and who had completed at least one required course in the major. Respondents included 22 students who were enrolled as geoscience majors and had taken at least one geoscience course at the time of the interview, eight respondents who had graduated with a degree in geoscience within the past 2 y, and one student who had switched from a geoscience major to a non-geoscience major.

In our study, eight students (five female, three male) self-identified as Hispanic/Latino or biracial including Hispanic/Latino (Hispanic hereafter) and 21 students (12 female, 9 male) self-identified as white, non-Hispanic/Latino or biracial including white, non-Hispanic/Latino (white hereafter). We excluded two nonwhite, non-Hispanic subjects from the dichotomous race/ethnicity analysis but included them in the gender analysis and classification. We acknowledge that these broad race/ethnicity designations

Example of a Critical Incident and Coding for a Positive Incident

What was the situation?
I was applying to a field volcanology course in Hawaii. I went to the post office.

What happened? What did the person do?
The postal employee helped me to send my application.

What was the result?
He was so excited to finally meet a volcanologist or somebody who's going to be a volcanologist that he asked to shake my hand.

IF NOT OBVIOUS: How did this experience affect the student's decision to major in geoscience?
I liked it. It was great. I was like, oh, my god, somebody likes volcanologists.

Major category: College factors Subcategory: Community socialization

FIGURE 1: Example of a positive incident.

are not ideal; however, our limited sample size precluded more detailed and culturally specific classifications. A small number of nontraditional students affected our sample age ($M = 25.8$ y, median = 23.0 y, range = 18–50 y).

To recruit respondents, we distributed flyers and sent blanket e-mails to current geosciences majors, recent graduates, and former majors at a large university in the southwestern U.S. We also solicited students who had received undergraduate degrees elsewhere and, within the past 2 y, had entered the graduate degree program at the study university. The average interview lasted about 45 min and followed a semistructured interview protocol (see Supplemental File 1). We encouraged respondents to recall as many types of experiences as possible and then asked follow-up questions during the interview about how respondents felt during the experiences, or critical incidents; these determined the outcome of the incident (Fig. 1). If the subject reported that the incident promoted geoscience major choice or retention, we labeled the incident “positive.” If the incident had opposite consequences, we labeled it “negative.” A white male geoscience graduate student conducted all interviews and coded all data.

After interviews were completed, we gave each subject received a gift card valued at \$25. We recorded all interviews on audio tape and took notes by hand. The recordings were transcribed via a secure and confidential service, and individual identifying information was subsequently removed from each transcript before CIT analysis. This research project received human subjects approval.

Our interviews yielded from 16 to 47 incidents ($M = 29.9$ incidents) each, or a total of 926 critical incidents. Of the 926 incidents, 721 (77.9%) resulted in positive outcomes and 205 (22.1%) resulted in negative outcomes. Each subject reported, on average, 23 positive critical incidents and seven negative outcome critical incidents (negative incidents hereafter). Though most subjects reported an overwhelming majority of positive incidents, some had nearly as many negative incidents as positive. Only one student reported more negative incidents than positive incidents.

Development of Classification

We examined all critical incidents together to develop our classification. We sorted and classified incidents based on the types of reported experiences. In their “geoscience pipeline” model, Levine et al. (2007) outlined four tiers of indicators of choice of major: middle/high school, junior college, 4-y college, and graduate school. Our study used many of these categories as a foundation for our classification system. We grouped critical incidents into three major, temporal categories: college factors, K–12 factors, and out-of-school factors. Not all groups contained equal numbers of incidents, and not all subjects reported incidents in all categories.

Within each of these broad, temporal categories, we further organized critical incidents into subcategories. We retained 11 subcategories from Levine et al.'s (2007) classification system, modified 12 subcategories, and identified 13 new subcategories and sub-subcategories (Fig. 2). College factors was the major category with the most critical incidents and subcategories ($n = 685$ critical incidents, $n = 14$ subgroups). Because our research focus was on undergraduates, we did not experience reported from graduate school. We combined junior college and 4-y college experiences for simplicity and due to a small sample of junior college incidents.

We organized all critical incidents that occurred in-school and before college into one major category: K–12 factors. Despite the large time range (i.e., 13 years), fewer critical incidents were identified here than in the college factors category ($n = 112$ critical incidents, $n = 10$ subcategories).

Finally, we identified a category encompassing incidents that occurred before grade school enrollment, occurred at indeterminate times, or were unrelated to K–12 education. For instance, one student reported that “Growing up, my mom always had science books around the house for me to read.” This critical incident could have occurred while the student was in grade school, but the timing was uncertain and it was independent of any educational setting. As such,

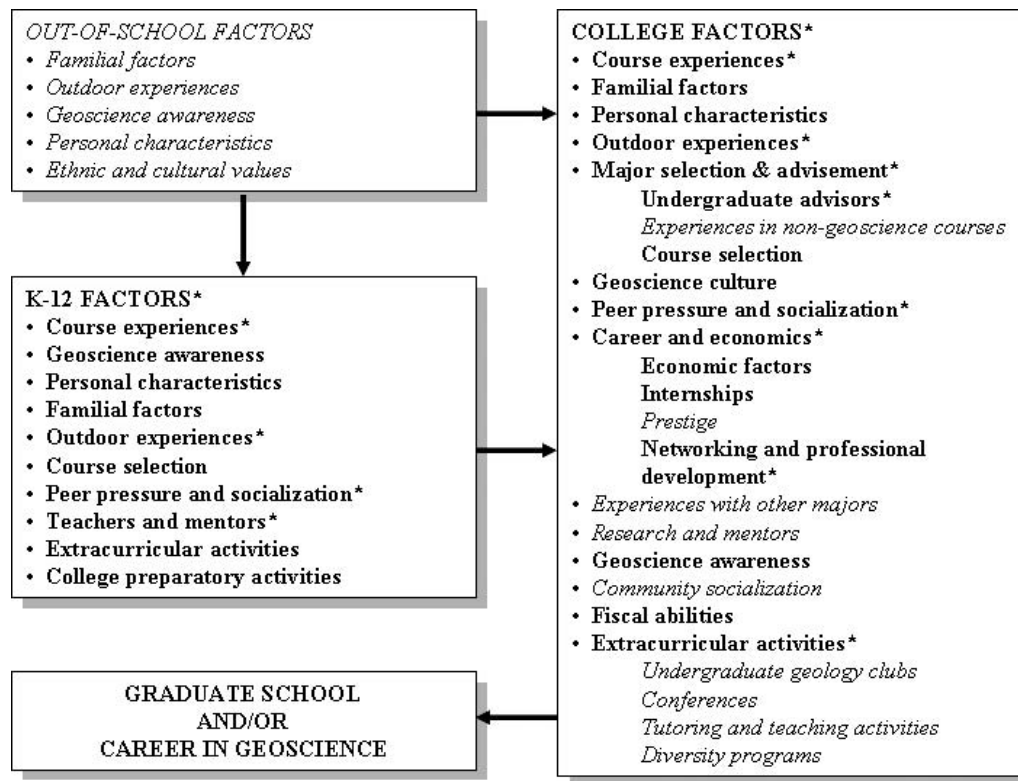


FIGURE 2: The critical incident classification as developed for this study. Subcategories are ranked by number of reported incidents. Bold text represents groups previously identified by Levine et al. (2007); an asterisk represents a previous category that has been modified. Text in italics represents new categories identified by this study.

we sorted the incident into the out-of-school factors category, which contained slightly more critical incidents than the K–12 factors category but was not as categorically diverse ($n = 129$ critical incidents, $n = 5$ subcategories).

We use the existence of a critical incident in a particular category or subcategory as an indicator of importance: the more critical incidents in that group, the more important that category or subcategory was to students. We interpret subcategories with a high ratio of positive-to-negative incidents as rough indicators for “what students like most” about the geoscience major. We interpret categories with a low ratio of positive-to-negative incidents as rough indicators for “what students like least” about the geoscience major.

For our race/ethnicity analysis, we classified subjects into two groups: Hispanic/Latino ($n = 8$) or white, not Hispanic/Latino ($n = 21$). Two subjects who self-identified as neither Hispanic/Latino nor white were excluded from these analyses. For our gender analysis, we used the full subject pool of 18 women and 13 men. In both analyses, we sought the presence of previously identified barriers to diversity by using differences in reported experiences as proxies. Our null hypotheses were that no relationship existed between tested subcategories and race/ethnicity or gender.

To evaluate the reliability of the classification system, we gave three anonymous raters brief training and asked them to sort a random sample of 50 incidents via SurveyMonkey. Two raters were male and one was female, all were white, and all were blind to respondent demographic data. We used IBM’s Statistical Package for Social Sciences (SPSS) to

calculate Cohen’s kappa. Since Cohen’s kappa is a coefficient of agreement, rather than a measure of percentage in agreement, we were able to account for the effect of agreement occurring by chance. We calculated values of 0.58, 0.48, and 0.46; these figures reflect our rater’s abilities to consistently classify incidents into our subcategories. Gremler (2004) notes that a Cohen’s kappa of 1.00 represents absolute agreement; our results were lower than Gremler’s reviewed CIT study average of 0.745. We speculate that overlap of our sub-subcategories was to blame for these somewhat unsatisfactory ratings.

The classification system allowed for rapid data retrieval and multiparameter comparisons. We used QSR International NVivo 10 to import, code, and organize the critical incidents. After query parameters were entered into NVivo 10, we generated data tables and subsequently exported data into SPSS. In SPSS, we used Chi-square tests on categorical and nominal variables (i.e., the presence of the tested incident) and analysis of variance tests on continuous variables (i.e., the number of incidents in a category or subcategory).

RESULTS

Popularity of Factors

We ranked the most commonly reported factors (Table 1). We found that career and economics had the highest positive-to-negative incident ratio; nearly all incidents were positive (Fig. 3).

TABLE I: Most popular critical incidents.

Category	Total Incidents (<i>n</i>)	Students Reporting (<i>n</i> , %)	Most Common (Average)
College factors	685	31 (100)	22.1
Course experiences	102	29 (94)	3.3
Familial factors	100	29 (94)	3.2
Personal characteristics	79	28 (90)	2.5
Outdoor experiences	67	28 (90)	2.2
Major selection and advisement ¹	57	28 (90)	1.8
Geoscience culture	53	27 (87)	1.7
Peer pressure and socialization	52	28 (90)	1.7
Career and economics ¹	44	21 (68)	1.4
Experiences with other majors	30	16 (52)	1.0
Research and mentors	29	15 (48)	0.9
K–12 factors	112	25 (81)	3.6
Course experiences	40	24 (77)	1.3
Geoscience awareness	18	11 (35)	0.6
Out-of-school factors	129	28 (90)	4.2
Familial factors	45	25 (81)	1.5
Outdoor experiences	29	20 (65)	0.9
Geoscience awareness	25	14 (45)	0.8
Personal characteristics	25	13 (42)	0.8

¹Aggregate category; see Appendix A for subcategories (Supplemental File 2, available online at <http://dx.doi.org/10.5408/14-038s2>).

Race/Ethnicity Analysis

Our limited sample revealed few differences by race/ethnicity across categories, subcategories, and sub-subcategories (Table II). However, Hispanic students reported

significantly more negative incidents in college than did white students (9.9 versus 6.0, $p < 0.05$). In the college factors category, Hispanics from this study reported more familial factor incidents, on average, than did whites (4.9

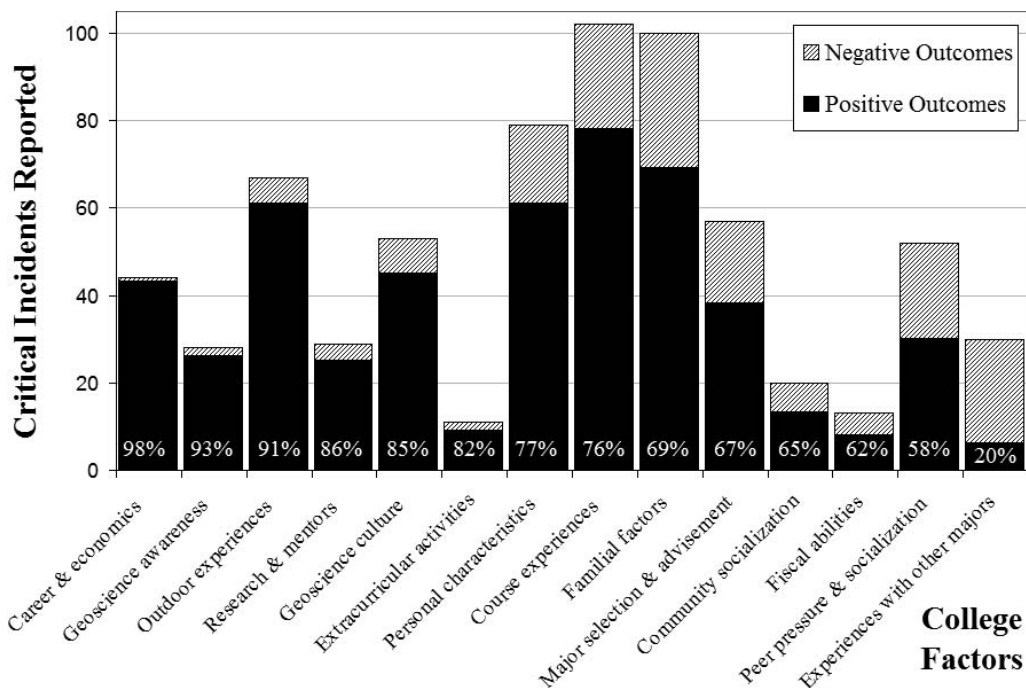


FIGURE 3: Stacked column graph showing ranking of college factor subcategories with the highest ratio of positive-to-negative outcomes on far left and the percentage of positive incidents shown in each bar. The total incidents reported in each subcategory are indicated by the relative height of each stacked column.

TABLE II: Number and proportion of white and Hispanic students providing selected types of critical incidents.

Category	White (<i>n</i> = 21)		Hispanic (<i>n</i> = 8)	
	Percentage	Average (<i>n</i>)	Percentage	Average(<i>n</i>)
Overall incidents				
College: Familial factors	90	4.9 ¹	100	2.6 ¹
Out-of-school: Outdoor experiences	81 ²	1.2 ¹	38 ²	0.4 ¹
Positive incidents				
Out-of-school: Outdoor experiences	81 ¹	1.2 ¹	38 ¹	0.4 ¹
Negative incidents				
College: Overall	90	9.9 ¹	100	6.0 ¹
College: Personal characteristics	52 ¹	1.0	13 ¹	0.1
College: Familial factors	24 ¹	0.6 ²	75 ¹	2.5 ²

¹Significant finding, $p < 0.05$.

²Significant finding, $p < 0.01$.

versus 2.6, $p < 0.05$). Three quarters (75%) of the Hispanic familial incidents were negative, which was significantly greater than the proportion of familial incidents that were negative for white respondents (24%, $p < 0.05$).

We also found that Hispanics from this study reported fewer out-of-school outdoor experiences than did whites (0.4 versus 1.2, $p < 0.05$). Furthermore, Hispanics reported fewer positive incidents in out-of-school outdoor experiences than did whites (0.4 versus 1.2, $p < 0.5$). All of these experiences, for both whites and Hispanics, were positive experiences. Finally, we found that more Hispanics from this study reported negative incidents regarding personal characteristics in college than did whites (52% versus 13%, $p < 0.05$).

Gender Analysis

Our sample revealed few differences by gender across categories, subcategories, and sub-subcategories (Table III). In the college factors category, we found differences based on gender in two subcategories: (1) career and economics

and (2) experiences in required nongeoscience courses. We found that men from this study were nearly twice as likely as women to report career and economics incidents (Table III); this disparity was driven by higher numbers of positive incidents reported by men (92% versus 50%, $p < 0.01$). Women from this study were more likely than men to report experiences in required nongeoscience coursework (50% versus 15%, $p < 0.05$); this disparity was driven by negative incidents. Of the women in the study, 44% reported at least one negative experience in these courses, compared to 8% of men ($p < 0.05$). In the K–12 factors category, we found that women from the study reported higher numbers of positive incidents than did men in the course experiences subcategory (1.2 versus 0.5, $p < 0.05$).

DISCUSSION

Descriptions of the Top 10 Factors

We highlight the most commonly reported factors across all categories (Table I).

TABLE III: Number and proportion of male and female students providing selected types of critical incidents.

Category	Male (<i>n</i> = 13)		Female (<i>n</i> = 18)	
	Percentage	Average (<i>n</i>)	Percentage	Average (<i>n</i>)
Overall incidents				
College: Career and economics ¹	92 ³	2.2 ³	50 ³	0.8 ³
Economic factors	69 ²	1.0 ³	28 ²	0.3 ³
College: Major selection and advisement ¹	92	1.4	89	2.2
Experiences in nongeoscience courses	15 ²	0.2	50 ²	0.8
Positive incidents				
College: Career and economics ¹	92 ³	2.2 ³	50 ³	0.8 ³
Economic factors	69 ²	0.9 ²	28 ²	0.3 ²
K–12: Course experiences	54	0.5 ²	78	1.2 ²
Negative incidents				
College: Major selection and advisement ¹	8 ³	0.2 ³	61 ³	1.0 ³
Experiences in nongeoscience courses	8 ²	0.1 ²	44 ²	0.7 ²

¹Aggregate category; see Appendix A for subcategories (Supplemental File 2).

²Significant finding, $p < 0.05$.

³Significant finding, $p < 0.01$.

Course Experiences

Course experiences, in both K–12 and college classrooms, were most often cited in a student's decision to major in geoscience. Most students reported that they experienced an enjoyable science course at some point before college; it was not necessarily a course with an Earth Science focus. One student discussed how his experience in a 7th-grade science course bolstered his interest in STEM:

"I remember going through the scientific method and doing experiments with magnets. We got nail filings, put the magnet over the top, and saw the magnetic field. It wasn't really geology, but relates to geophysics for me now."

At the college level, positive experiences in introductory geology courses led many students directly into the major (e.g., Holmes and O'Connell, 2003; Houlton, 2010). In our study, 94% of students reported a college course experience; 76% of these were positive. Some exceptionally personable and engaging instructors steered students into geoscience. One student reported:

"I never really considered becoming a geology major until about halfway through my geology course. The professor approached me and asked if I had ever considered it. It was pretty much right at that moment that I decided to switch."

Consistent with other studies, many of our respondents reported transferring into geoscience from other majors after enjoying an introductory course (e.g., Hoisch and Bowie, 2010; NRC, 2013).

Familial Factors

Previous research established the importance of family influences on education, choice of major, and development (Seymour and Hewitt, 1997; Martin, 2000; Holmes and O'Connell, 2003; Libarkin and Kurdziel, 2003; Levine et al., 2007; Munro, 2009; Stokes et al., 2014; Callahan et al., 2015). For children in an out-of-school setting, parents and other family members directly communicate information and attitudes about science. In all of our out-of-school familial factor critical incidents, family members encouraged positive attitudes toward science, which subsequently induced interest in geoscience. These types of interest-building experiences were described by 81% of interviewees and represented 35% of all out-of-school factors categorizations.

College familial factors were reported by 94% of subjects. Students typically recalled the reactions of family members, both positive and negative, toward their decision to major in geoscience. In some cases, students reported that they came home from university classes and shared geoscience information with interested and supportive family members. In other cases, students reported that they felt alienated from family members who did not understand or care to learn about geoscience. Some students were discouraged enough to stop communicating with family members about their choice of major. However, overall, most (66%) of these college familial factor incidents were positive.

Personal Characteristics

This subcategory includes critical incidents that relate to a student's personality, values, goals, and capacity to make life changes. Personal characteristics "reflect a student's

ability and desire" to persist in the major and are indicators of how well the individual fits in the geoscience major (Levine et al., 2007, 463). In this context, "fit" represents how individuals perceive their ability to share values, interests, and expectations within a new culture. For instance, a student reporting positive personal characteristic incidents in college will say that the major is "perfect for me" or that geoscience is something that "I've always wanted to pursue."

In our study, 90% of students reported at least one personal characteristic incident; 77% of these were positive. One student reported that "I like the solving the puzzles of geologic history." Another student discussed the breadth of the major and how she appreciated learning about the natural world in her courses:

"There are so many different things to do in classes. You could be talking about planetary evolution and the universe one day and then the evolution of life the next day. ... Having this type of knowledge is rewarding and makes people's lives more vibrant."

We placed some intriguing, negative incidents into this category. One woman noticed stark gender differences when comparing herself to her male peers in STEM:

"Girls are just brought up differently. I guess it's pretty normal for women not to excel as much in math and science classes. Geoscience is pretty loaded with physics, chemistry, and math. Do I really want to do this?"

In this incident, the student reported that her gender felt like a limiting factor in her ability to succeed in STEM. Another woman responded more positively when queried about her experiences as a woman in STEM:

"I know that there's a big difference between the numbers of men versus women in the science field, and I thought it was cool that the first two people that I met in the geoscience department were women."

These anecdotal data, and others like them from our female respondents, echo the STEM literature that proposed or established the presence of subtle biases, like stereotype threat (e.g., Larocque, 1995; Holmes and O'Connell, 2003; Libarkin and Kurdziel, 2003; Correll, 2004; Ferreira, 2003; Hazari et al., 2013; Hill et al., 2010; Miyake et al., 2010; Ceci et al., 2011; Moss-Racusin et al., 2012; Avallone et al., 2013; NRC, 2013).

Outdoor Experiences

Influencing their feelings about STEM, outdoor experiences are formative experiences for some geoscience majors (e.g., Holmes and O'Connell, 2003; Levine et al., 2007). In college, 90% of students reported at least one outdoor experience; 91% of these incidents were positive. Students reported that field experiences made them into better scientists, helped them to understand course content more thoroughly, and enhanced their enjoyment of the outdoors. In particular, students cited longer, multiday field trips and geology field camp as significant outdoor experiences. A small number of students reported that they did not like field trips, for various reasons.

We found that outdoor experiences that influenced STEM attitudes, as part of out-of-school activities (i.e., while “growing up”), were reported by 65% of students. Critical incidents from this subcategory included stories of family camping trips, road trips to national parks, visiting caves and abandoned mines, and being outdoors during extreme weather. A few students reported outdoor experiences during high school, such as field trips in honors courses.

Major Selection and Advisement

This subcategory represents an aggregate of three sub-subcategories related to student experiences within the major: course selection, experiences in nongeoscience courses, and undergraduate advisers. In our study, 90% of students reported at least one incident in this subcategory; 67% of these incidents were positive. Course selection incidents included student experiences related to choosing geoscience courses and were reported by few students. Some students reported that some required geoscience courses fit well with their plan of study while other courses did not fit, or were not offered at the right time for their schedule.

Experiences in nongeoscience courses included classes that were required for the major but were offered outside of the geoscience department. Typically, these critical incidents resulted from courses such as chemistry, physics, and calculus. Of the incidents in this sub-subcategory, 72% were negative. One student reported that her experience in a nongeoscience course nearly drove her from the major:

“I enjoy math but I’m not very good at it. I considered switching from geology into hydrology or atmospheric science because I couldn’t hack the math.”

For these students, negative experiences in required coursework were barriers to persistence that could have resulted in leaving the major (e.g., Seymour and Hewitt, 1997). This anecdote is consistent with a generalized stereotype threat, which undermined female success in math and physics courses, that was found by Miyake et al. (2010) and others (e.g., Hill et al., 2010; Ceci et al., 2011).

Critical incidents related to undergraduate advisers were identified as important experiences by 84% of students. In many reported cases, a departmental adviser facilitated transition into the major after a positive experience in an introductory course. We found that nearly all (91%) undergraduate adviser incidents were positive. One enthusiastic student reported that his meeting with the adviser helped him through a transition from another university. “I’m sticking with the major,” he said. “To be known on a first name basis feels good, especially at a large college that has tens of thousands of students.”

Geoscience Culture

This category refers to social interactions that take place within the geoscience major. We distinguished these incidents as separate from personal characteristics because our respondents perceived the experiences as being unique to the major. Personal characteristics combine with geoscience culture to affect how a student fits in. We identified two types of experiences that 87% of students reported in this subcategory: a type of camaraderie that students perceived as being unique in geoscience courses and the possession of

a rock collection that was updated, shared, and discussed in a social context.

An example of an incident from the former type was reported by a male student:

“I could care less about meeting anyone in my general education classes. But now that I’m in a field where people share the same interest, it’s much easier to carry on a conversation. You build friendships and it’s cool.”

Having a peer support system within the major helped this student to feel welcome. A different student described the role of outgoing faculty in this culture:

“You have a different breed of people in the geosciences. They’re very intelligent and capable of doing important research, but they can still have a beer on the weekend and play in the dirt.”

We recorded some negative geoscience culture incidents as well. One student, a Hispanic woman, described how she felt challenged to fit in with geoscience culture:

“You really don’t see five foot two inch little Hispanic girls going out into the field and wanting to collect rocks. It intimidates me because everyone else is Caucasian, taller, or has more scientific experience.”

In this case, the student’s view of herself conflicted with her perception of the geoscientists that she knew. A white woman discussed a similar disconnect with geoscience culture:

“There’s a stigma to being a girl in geoscience. Women in geology are thought of as these hippie type ladies, very natural, and sometimes I feel like people expect you to not try to be attractive and not to shave your legs. I dressed up for something once and someone told me that I didn’t look like a geologist. That was weird.”

In both examples, the student’s experiences with not meeting perceived cultural expectations of a geoscientist negatively affected their persistence in the major. These anecdotes are consistent with others who noted that subtle biases play a role in undermining the confidence of women and URMs in STEM (e.g., Larocque, 1995; Holmes and O’Connell, 2003; Libarkin and Kurdziel, 2003; Hill et al., 2010; Avallone et al., 2013).

For many students, collecting rocks, minerals, and fossils began as a hobby during childhood. We classified these types of incidents as “out-of-school factors: geoscience awareness” or elsewhere, depending on the circumstances. In contrast, we include the social context of rock collecting as a distinctive part of the college geoscience culture. Many students reported that they prospected, purchased, and discussed rocks and minerals with geoscience students and faculty. Often occupying a decorated location in their homes, the students reported that their collections were the bridge between their major and their nonscientist friends and family. One student reported:

“My house is littered with rocks. Everywhere I go, I pick up a new rock. Half of them become souvenirs that I give to

people. My friends who aren't geologists have little collections because of me."

Peer Pressure and Socialization

These incidents involved peer reactions to students sharing their decision to major in geoscience. We defined peers as friends outside of the geoscience major. In our study, 90% of students reported at least one incident in this subcategory; 58% of these incidents were positive. Typically, students described the experience as complex; some friends were supportive, some were not. For instance, one student stated that she enjoyed explaining the nature of geoscience careers to friends who were not familiar with the field. "I like explaining my choice of major," she said. "Since it's not a typical career, it gives me an opportunity to talk about what I like to do." However, the same student also reported frustration when some of her peers provided negative feedback:

"Geoscience is underappreciated and not well publicized. People have a misinformed idea—they think of it as a lazy science that doesn't carry much clout. People think I'm weird for pursuing the major."

Career and Economics

We found that 68% of students reported at least one incident in this subcategory; 98% of these incidents were positive. Students reported enjoying internship opportunities in the public and private sectors, connecting with professional geoscientists through the U.S. Geological Survey, and interviewing with energy company recruiters. Six students reported that their university had recently earned a high national ranking for its geology program; this prestigious accolade was a major recruiting factor for the students. One student described his thought process:

"When I chose the major, I felt like I had a future. I know that with a lot of the other majors, you don't get a job afterwards. I felt that geology would be different."

Experiences With Other Majors

Many geoscience majors transfer from other programs (e.g., Houlton, 2010; Levine et al., 2007). From our study, 52% of the students reported an experience with other majors; 77% were negative. Many of the issues that we documented (e.g., disengaged faculty, poor teaching, loss of interest in the major, inadequate advising, morale undermined by competitive culture, and lack of peer study group support) were identical to those identified by Seymour and Hewitt as reasons students leave STEM majors. One female student described several factors in her rationale for switching from chemistry into geoscience:

"My experience was that chemistry people were very into themselves. They were much more closed and not so laid back. And, women and men were very separate. I didn't have a single guy friend in chemistry. It was almost like 'you're a girl; you don't know this.'" (Seymour and Hewitt 1997, 46)

Again, our anecdotal data are consistent with subtle biases found in STEM courses (Hill et al., 2010; Miyake et al., 2010; Hazari et al., 2013).

Research and Mentors

Undergraduate research experiences were reported by 48% of the respondents; 86% of these incidents were positive. For some, the idea of working with well-known faculty on international projects was appealing. One respondent reported that he was involved in some "really cool" research with a faculty member who works in the Andes Mountains. Another student was excited to discuss their research with a professor who works in Tibet. Both of these students became interested in research because they had previously taken courses with their mentors. Where faculty and graduate students work with undergraduates on research projects, demonstrable impacts on the retention of undergraduates, and particularly women and URMs, have been documented (e.g., Bemby et al., 1998; Houser et al., 2013; NRC, 2013).

Race/Ethnicity and Gender Differences

In our small sample, we found few differences across all categories, subcategories, and sub-subcategories by race/ethnicity or gender. However, we reiterate that our failure to find many differences does not necessarily indicate that race/ethnicity or gender differences do not exist. There are several possibilities for our inability to find differences, including (1) these differences do not exist, (2) our interview methodology was not properly suited for our research questions, and (3) our sample was too small to determine whether additional differences existed. No URMs from this sample reported an overt encounter with racial discrimination as described in Levine et al.'s (2007) pilot study. It is possible that our respondents had not experienced discrimination, they were unwilling to report discrimination, our interview protocol was not suitable, or discrimination incidents are less likely to be reported to a white interviewer—or some combination of these factors.

Race/Ethnicity Factors

We found that Hispanic students at our study institution reported more familial factors, and more negative familial factors, than did white students. This is not the first research to show that Hispanic STEM majors are strongly affected by familial factors. Munro's (2009) dissertation showed how families could steer Hispanic students toward, or away from, STEM. Though qualitative in design, this study made a strong argument that Hispanic students faced pressures toward careers with high visibility (e.g., medicine and law). Similarly, Martin (2000) demonstrated how cultural devaluing of math led African Americans to reject math, which he subsequently argued was partially responsible for the underrepresentation of African American students in STEM. The relatively limited cultural familiarity with the practices and norms of higher education puts many Hispanic students in an uphill battle for college degrees (Chapa and de La Rosa, 2006; Hill et al., 2010). Furthermore, Callahan et al.'s (2015, 99) social capital model described how a student's engagement with family and friends could create stronger ties to the geoscience major than relationships with acquaintances, peers, and instructors. With a critical piece (i.e., familial support) of social capital missing, it follows that

a Hispanic major in this situation could feel left out of the geoscience community. In addition, Reyes *et al.* (1999) found that Hispanic women are particularly susceptible to familial influence. They wrote that “parental overprotection of and strictness with females” restricts Hispanic women from pursuing careers in male-dominated areas (Reyes *et al.*, 1999, 378). Our interpretations are consistent with this finding.

Compared to white students, our sample of Hispanics reported fewer out-of-school outdoor experiences that contributed to the formation of positive STEM attitudes. This lack of outdoor experiences negatively influenced choice of a geoscience major. We find that enjoyable, informal outdoor experiences are intrinsic and important components of the geoscience major. Furthermore, many students reported choosing geoscience because it fulfilled a lifelong desire to work outdoors. Previous research has established that Hispanic children do not spend as much time outdoors as white children (Whitney *et al.*, 2005; Outdoor Foundation, 2006; see, however, Larson *et al.*, 2011). Stokes *et al.* (2014, 53) described how geoscience is tailor-made for white youth who have grown up experiencing the outdoors but might not be the best fit for Hispanic youth with fewer outdoor experiences. They argued that more informal outdoor experiences are needed to help Hispanic youth see themselves as geoscientists.

We found that, compared to white students from our sample, fewer Hispanics reported negative experiences involving personal characteristics (*i.e.*, how well they fit with the geoscience major). This suggests that Hispanic students from our sample either felt a better fit than did white students in the geoscience major or that Hispanic students from our sample hesitated to report negative feelings regarding personal issues with the geoscience major. In the latter case, it is possible that the Hispanic students from our sample did not wish to reveal these feelings to a white interviewer. Since we found little in the data to support further analysis, we withhold further speculation.

Gender Factors

Women from this study reported significantly fewer career and economics-related incidents in college than men. This suggests a difference in how women and men are attracted into geoscience. For the women in this study, employability and salary, which are often emphasized in geoscience recruiting, were not the most important factors in the decision-making process. It is possible that the women from this study simply did not experience recruiting that piqued their career interests; they chose the major for other reasons. We speculate that other factors, such as course experiences and personal characteristics, may combine to draw women into geoscience. These findings are consistent with the breadth of research on women in STEM careers (*e.g.*, Macfarlane and Luzzader-Beach, 1998; Holmes and O’Connell, 2003; Hill *et al.*, 2010; Canetto *et al.*, 2012; NRC, 2013). However, we propose that the literature on career capital—which recognizes the value of skills, knowledge, and personal attributes that produce economic value—could guide future inquiry into this area (*e.g.*, Ceci and Williams, 2010; Duberley and Cohen, 2010; Ceci *et al.*, 2011).

Women from this study were more likely than men to report struggles with nongeoscience STEM courses in

college (*e.g.*, chemistry, physics, and calculus). Since these courses are required for geoscience majors, this represents a potential barrier for women in geoscience. As Hill *et al.* (2010) explained, girls generally do better than boys in math and science courses in high school. Thus, we find it unlikely that all of the women from our sample were unprepared for these courses.

Miyake *et al.* (2010) determined that a “stereotype threat” exists for women in college math and physics courses and that this issue affected the diversity within their physics major. They explicitly noted how this stereotype, if unaddressed, caused women in the courses to receive lower scores on course exams and tests (see also Hill *et al.*, 2010). Though some responses from our subjects were consistent with this interpretation, we saw no evidence of stereotype threat in the geoscience major or its required courses in the incidents provided by our respondents. Another possibility could be explained via Moss-Racusin *et al.* (2012), who determined that women are perceived by both men and other women to have inferior STEM skills. If this were the case, instructors in these courses might inadvertently reinforce the perception if they are not familiar with the bias. Further still is the possibility that men tend to overestimate their abilities in STEM (*e.g.*, Correll, 2004). In this scenario, socialization within these courses could lead women to question their own abilities relative to their male peers.

Finally, women from this study reported over twice as many positive K–12 course experiences as men. We attribute this difference to female advantages over males in K–12 courses. Catsambis (1994) found that women outperformed men in algebra, geometry, and overall coursework before 9th grade.

Limitations

This is the first study to comprehensively document and compare the experiences of geoscience majors by race/ethnicity and gender. Our sample size ($N = 31$; 926 critical incidents) and geographic scope are small. In addition, our statistical testing only identifies differences between categories and variables. Ideally, we would include samples of Hispanics from additional institutions, as well as African Americans and Native Americans. We would gain more statistical power with a larger sample.

Our hypothesis testing only allows us to identify factors for which a statistically significant difference exists. In this study, our approach tests these factors by race/ethnicity and gender. Our failure to find differences does not mean that the factor is unimportant, only that the importance does not differ based on our study variables. Without measures of classification saturation (*i.e.*, comprehensiveness), we cannot claim to have captured all of the important factors. In addition, we interviewed only one person who switched out of the major. These limitations could have prevented us from a more balanced understanding of the factors affecting student choice, or rejection, of a geoscience major.

IMPLICATIONS

Outstanding experiences in introductory courses, supportive family members, personal characteristics that fit with the major, and enjoyable field experiences were the most important factors in choice of a geoscience major for

our sample. We view these factors as crucial tools for improving recruitment and retention. Prospective majors will gain a better understanding of geoscience if recruiting materials discuss the full range of experiences to be encountered. For example, recruiting presentations could incorporate photos and testimonials from current students regarding the travel and field experiences that they enjoy the most about the major. A listing of potential undergraduate research opportunities, along with a few anecdotes from mentors and students researchers, would similarly address another need.

For many prospective geoscience majors, a major challenge entails convincing skeptical family members that geoscience is a desirable career choice. For prospective Hispanic geoscience majors at our study institution, the response must be more robust to address familial concerns. For example, professional development and career literature produced by societies such as the American Geosciences Institute could fulfill this need. Families should be brought on board at the same time as students to improve recruitment. Munro offered suggestions for such parent education programs:

“These programs should be community-based, rather than school-based, and they should be offered bilingually. These should have the aura of family events, rather than overtly school-related. Their purpose would be to strengthen students’ and parents’ vision of educational and professional goals and to make the stepping stones to reaching those goals transparent.” (Munro, 2009, 232)

Some challenges to recruiting Hispanic geoscience majors require long-term solutions. For example, many students reported that they chose geoscience because they wanted a career that allowed them to work outdoors. If a student grew up with many positive outdoor experiences, then majoring in geoscience might provide an opportunity for continuing outdoor activities. However, if a student grew up with fewer or no positive outdoor experiences, this motivator would be absent. To rectify the situation, we would encourage programs (e.g., Outward Bound) to increase the participation of Hispanic youth and their families in outdoor activities.

Showcasing the wider attributes of geoscience will improve the recruitment and retention of women. Emphasizing geoscience awareness (e.g., demonstrating the importance of geoscience in our daily lives), providing fulfilling outdoor experiences, and offering undergraduate research opportunities are strategies that can complement the positive impact of the existing demand for geoscientists in career choice decisions. In addition, simply discussing underrepresentation issues in introductory geoscience courses has the potential to enhance female interest in the major (after Hazari et al., 2013). This knowledge may be useful for developing recruiting materials (e.g., Web sites) that are gender neutral (e.g., Montelone et al., 2006) and place emphasis beyond career options, salary information, and employment statistics. Recruiting Hispanic women into geoscience is doubly challenging: career information must be redesigned with broader appeal, and family members should be made aware of the benefits of geoscience employment.

CONCLUSIONS

Designing undergraduate geoscience programs to meet future demands will rely heavily on attracting majors from all sectors of the population. We found the most important factors in the choice of a geoscience major in our sample, and we suggest employing these factors in recruiting practices. Exceptional instruction in introductory courses propels students into the geoscience major. This momentum can be either sustained or diminished by family members; for the Hispanic students in this study, it was the latter. Once in the major, the students in this study enjoyed field and research experiences, helpful academic advisement, and a strong sense of fit with their personal goals and attributes. Students also reported that they valued being a part of the culture of geoscience.

From our study sample, we identified difficulties in recruiting Hispanic students and their families, fewer outdoor experiences for Hispanic youth, and recruiting that focuses on careers and is unintentionally geared toward men. Until they are addressed in earnest, these obstacles will continue to prevent geoscience from attracting and retaining diverse populations of undergraduates. Increased opportunities for outdoor experiences for Hispanic youth should bolster diversity in future generations of geoscientists. We emphasize the value of outreach and call on professional societies and funding agencies to support this effort.

This study was not designed to identify specific biases endemic to women in geoscience, and we consider our evidence anecdotal at best. However, women from our sample reported additional challenges in math and physics courses that were required for the geoscience major, and we interpret this as useful information for faculty and academic advisers. Students can, and should, be steered toward STEM courses that support the retention of women.

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