The True Cost of Field Education is a Barrier to Diversifying Geosciences

Antoinette Abeyta
Math and Science Division, University of New Mexico-Gallup, 705 Gurley Ave, Gallup, NM, 87301, USA.
Email: abeytaant@unm.edu
Twitter: @variolax

Anjali M. Fernandes
Department of Earth and Environmental Sciences, Denison University, 100 West College Street, Granville, OH, 43023, USA.
Email: anjali.fernandes@denison.edu
Twitter: @climbing_ripple

Robert C. Mahon
Department of Earth and Environmental Sciences, University of New Orleans, 2000 Lakeshore Drive, New Orleans, LA 70148, USA.
Email: rcmahon@uno.edu
Twitter: @RobertCMahon

Travis Swanson
Department of Geology and Geography, Georgia Southern University, P.O. Box 8149, Statesboro, GA, 30460, USA.
Email: tswanson@georgiasouthern.edu
Twitter: @traviseswanson

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*Antoinette Abeyta[1]
Anjali M. Fernandes[2]
Robert Mahon[3]
Travis Swanson[4]
[1.] Math and Science Division, University of New Mexico-Gallup, 705 Gurley Ave, Gallup, NM, 87301, USA
[2.] Department of Geosciences, Denison University, 100 West College Street, Granville, OH, 43023, USA
[3.] Department of Earth and Environmental Sciences, University of New Orleans, 2000 Lakeshore Drive, New Orleans, LA 70148
[4.] Department of Geology and Geography, Georgia Southern University, P.O. Box 8149, Statesboro, GA, 30460, USA

**Corresponding Author: Antoinette Abeyta, Math and Science Division, University of New Mexico-Gallup, Gallup, New Mexico, USA, E-mail: abeytaant@unm.edu*

Fieldwork is considered critical to developing technical skills in geoscience education, and typical undergraduate degrees require more than 30 days in the field. Tuition costs of enrolling in field camp are acknowledged as a barrier to participation in geosciences; however, the cost of participation in field activities may also include the cost of personal field gear (e.g., hiking boots, backpacks), travel, lost wages, and dependent care. To neutralize impacts of systemic bias on the future geoscience workforce, it is imperative that we (a) examine how the cost of field work presents barriers to participation, and (b) intentionally direct financial resources towards dismantling these barriers. We show that the financial burden associated with a week-long field endeavor, excluding potential tuition costs and including personal field gear, domestic air travel, lodging, dependent care, and lost wages range from 1,697 to 2,601 U.S. dollars (USD), and can be as large as 3,824 USD. This sum is likely to be out of reach for individuals from low-income groups, and represents a fundamental barrier to diversifying participation in our field. Budgets for inclusive field research and education must account for and accommodate these financial challenges to broader participation.

Earth is home to many diverse communities and cultural heritages. If we aspire to generate innovative and equitable scientific solutions to current and future environmental problems, the workforce that drives progress in geosciences must be equally diverse [1]. The geosciences, however, have persistently maintained the lowest rates of ethnic and racial diversity among all STEM fields [2]. Less than 9% of all students enrolled in geoscience graduate programs in the U.S. are from historically excluded groups (Black, Latinx, Native American) [3]. Identifying and removing the barriers that limit participation in geosciences is therefore critical to achieving our vision of a diverse geoscience workforce.

Direct observations of Earth's natural phenomena are foundational in geosciences [4], emphasizing the importance of field education. A bachelor's degree in geoscience typically requires 30 to 60 days of field experience [5]. For many individuals, field experiences provide the first opportunity to apply theoretical and practical concepts learned in the classroom. Coupling visits to novel locations with the shared thrill of discovery among peers, field experiences can be transformative, educationally enriching, and community building endeavors for junior scientists. The powerful impact of shared field experiences is reflected in the geoscience identity; participation in fieldwork is often seen as a rite of passage that underpins membership in the geoscience community. The depth and range of the technical skills developed during field experiences (e.g., educational field trips, field camp, field-based research, or internships) is used to qualify an individual's educational background [6]. Yet, research that addresses how the costs related to participating in field experiences may constitute barriers to participation and success is relatively scarce.

Enrollment in a multi-week field camp is a recognized barrier to participation in geosciences [7,5,8,9]. It is estimated that the tuition costs of field-based courses average 4,000 USD. In addition to tuition costs, other financial burdens associated with field work can pose additional barriers. When accounting for the true cost of participation, such as loss of wages and travel, multi-week field-based courses can cost up to 16,000 USD[10]. However, geoscience curricula typically include shorter-term weekend to weeklong field outings, which can also include similar costs that pose a significant barrier early in an undergraduate program. To our knowledge, a published quantitative assessment of these financial burdens does not yet exist.

In this study, the "hidden" financial costs of participation in a five-day field experience are systematically quantified. Items included in this analysis are: (1) the cost of adequate field gear, (2) the cost of domestic travel to field sites, (3) loss of wages, and (4) the cost of dependent care. The analysis was conducted for a five-day field experience that includes domestic travel within that five-day interval. The range of costs are presented as the 25th and 75th percentiles of the assembled datasets, as well as the 95th percentile to represent a high estimate for each category. The 25th and 75th percentiles represent the likely range of costs incurred.

A. The cost of personal field gear

Inadequate field gear can present significant health and safety risks to participants [11], but adequate personal field gear and protective equipment (e.g., sturdy hiking boots) is costly. Fieldwork budgets do not normally include individual field equipment as a cost; instead, budgets are typically constructed with the assumption that participants already own the gear needed to conduct field work safely [12]. As numerous studies have shown, the cost of adequate outdoor gear is a barrier to participation in outdoor activities, particularly for minoritized groups [13–15]. The basic field gear needs (e.g., sturdy boots, wool socks, backpack, rain gear) are less likely to already be owned by students from underrepresented groups. For this study, estimated costs of essential personal field gear included a field pack, a pair of hiking boots, a raincoat, a set of fast drying pants, a sports bra, a pair of wool socks, a hat, a pair of work gloves, a water bottle, a personal first aid kit, sunscreen, a notebook, a hand lens, a package of pencils, and a package of markers.

If the individual were to purchase just one of each item, the most likely range of this initial investment would be 262 to 676 USD, with a maximum estimate of 1,322 USD (Figure 1). For a five-day field experience, we deemed that the minimum necessary gear would include 2 pairs of pants and 3 pairs of socks. The range of costs in this estimate varied from 303 to 759 USD, with a maximum estimate of 1,528 USD.

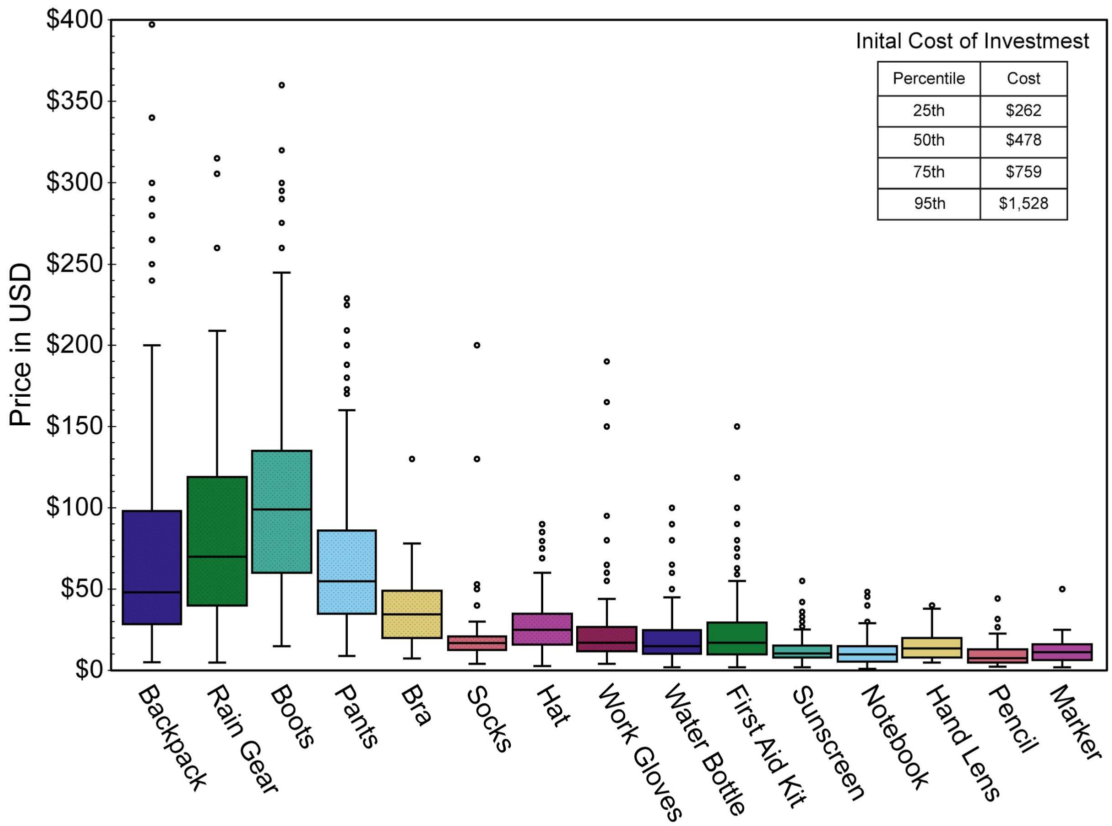

Figure 1: Distribution of costs of essential field gear. Dots represent values outside of 2 standard deviations.

As consumer products can be marketed differently to women and men, we examined the results to see if there is a price difference between women's and men's gear. Apart from socks, which had a similar range and price distribution, all gendered items (boots, rain gear, pants, and work gloves) showed a statistical difference in price. The cumulative difference between women's and men's gear ranges from 61 to 182 USD more, with a maximum estimate of 200 USD; meaning that individuals purchasing women's clothing will, on average, spend more than their male counterparts for their field gear (Figure 2).

The average clothing sizes used by women in the U. S. is 16-18 [16]. However, most brands label sizes that are 16 or larger as "plus" sizes in which limited options for clothing are provided. A comparison between plus size and standard size gear (rain gear, pants, sports bras) shows a statistical difference in price for rain gear and bras. Individuals who purchase plus size women's clothing pay 35 to 63 USD more than those purchasing standard sizes. Estimates that accommodate the intersection of size and gender difference in gear show that plus size women's gear will cost between 35 and 63 USD more than women's standard sized gear and between 98 and 245 USD more than men's gear.

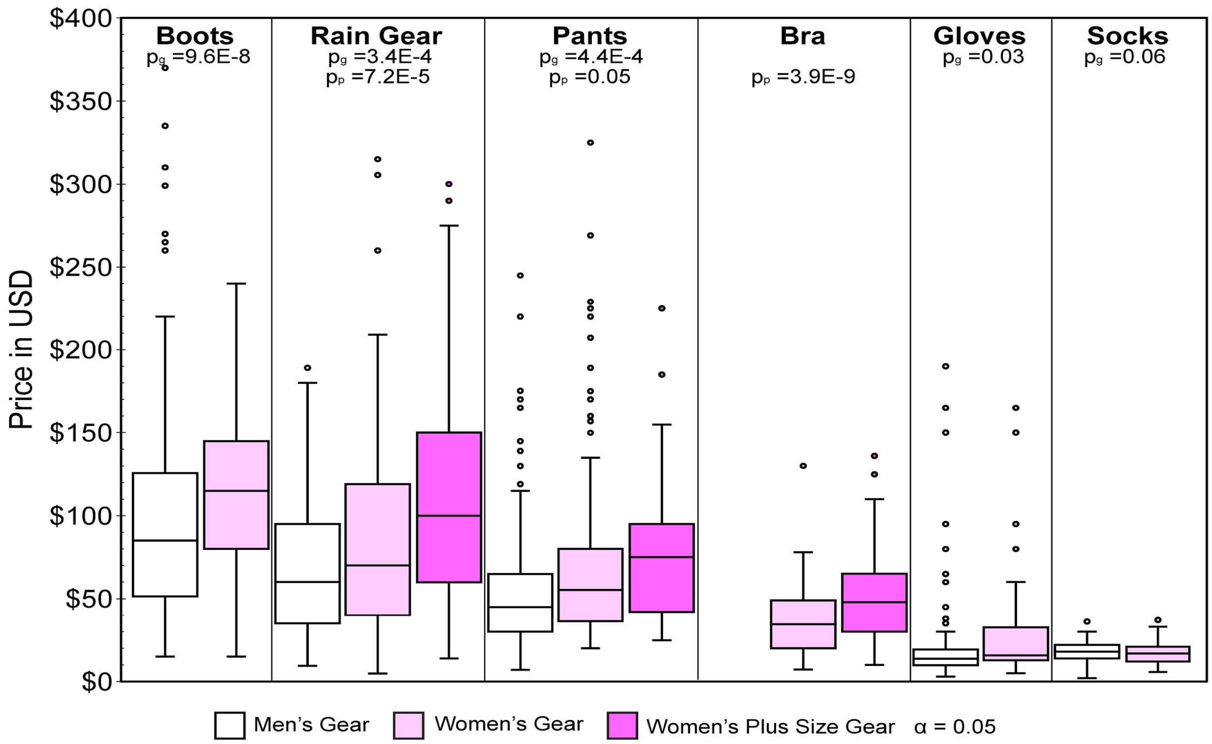

Figure 2: Price difference of gendered field gear items and plus size gear, women's plus size gear is shown in dark pink, women's standard size gear is shown in light pink and men's gear is shown in white. An additional 30 to 50 USD cost associated with bra purchases must be incurred by individuals that require them. Dots represent values outside of 2 standard deviations. Significance tests were conducted at α = 0.05, p_g refers to significance tests between men's and standard size women's gear, p_p refers to significance tests between standard size and plus size women's gear.

The collected data do not show a statistically significant difference in the prices of standard and plus size pants which at first glance seems at odds with the lived experience of many field scientists. This is because significantly more offerings from high-end brands were found in standard sizes but did not exist in plus sizes. Disregarding any data points outside the interquartile range for both standard and plus size pants reveals a statistically significant difference in price (α

= 0.05). When this difference is accommodated, plus size women's gear is estimated to cost between 35 and 67 USD more than women's standard sized pants and between 51 and 103 USD more than men's gear, with a maximum estimate of 149 USD. Although this data artifact is noteworthy and points to bias in the available data, we have chosen not to include this data treatment in the final comparison plotted in Figure 2. Additionally, as searches for maternity and adaptive clothing yielded few results; a robust range could not be calculated for comparison. It is expected that individuals who require maternity or adaptive clothing will need to pay more for gear or use inadequate gear to try to meet their needs.

As students progress in their geoscience careers and accumulate field gear, this cost will decrease. However, it is important to note that gear is subject to wear and tear, and that student bodies may change over time such that students will also need to maintain, repair, or replace their gear repeatedly. These estimates do not include gear for field work at sites that require specialized preparation (e.g., sub-zero temperatures, swimming).

B. *The cost of domestic travel to field sites*

Meals and incidental expenses varied from 244 to 264 USD, with a maximum estimate of 304 USD; domestic flights for a five-day trip varied from 381 to 477 USD, with a maximum estimate of 938 USD; lodging varied from 275 to 368 USD, with a maximum estimate of 2,140 USD (Figure 3). The combined cost related to travel ranges from 900 to 1,108 USD, with a maximum estimate of 1,584 USD. Individuals can choose to reduce costs by sharing lodging arrangements; however, this practice has been shown to introduce potential safety risks associated with sexual misconduct [17]. This estimate is based on US citizens traveling domestically. Additional costs related to the acquisition of passports and visas, as well as airfare and lodging, will be required for international travel. International students who have travel limitations will incur additional financial burdens.

C. *Wage losses*

An estimated 80 percent of undergraduate students work while enrolled in classes [18]. Overlapping fieldwork and employment schedules can create financial stress and negatively impact student productivity and wellbeing [19]. Extended amounts of time away from their employment will have direct impacts on students' financial obligations (e.g., rent).

For this work, the loss of wages is calculated by using US federal and state minimum wage laws, and are therefore the lowest compensation range possible. The calculated loss of wages varied from 290 to 433 USD, with a maximum estimate of 491 USD (Figure 3). In 2017, women on average earned 82% of what men earned; women of color earned as little as 55% [20]. Women, and especially women of color, would therefore have to work more hours on average to recover the income that is equivalent to that lost by their peers who are men [20].

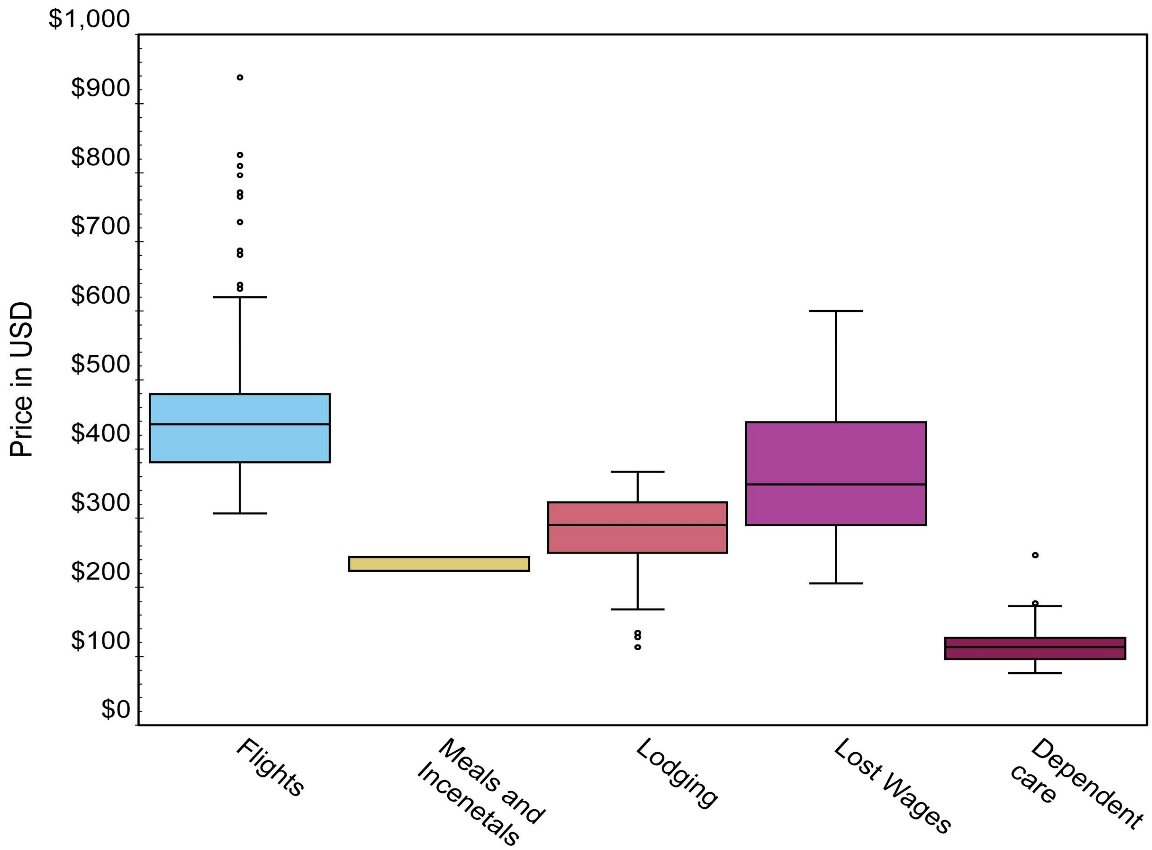

Figure 3: Distribution of costs associated with travel, meals, lodging, loss of wages and dependent care. Dots denote observations outside of 2 standard deviations.

D. Costs associated with dependent care

Travel for fieldwork commonly means that students must make arrangements for dependent care. As dependent care expenses are not typically considered in the costs of participation, the associated financial burden can become particularly acute for low-income students and their families [21]. Subject to availability, which varies with time of the year, lead time, geography, employment factors, flexibility, quality, and cost, suitable dependent care options may not be available for students [22]; therefore, fieldwork will also not be an option for them.

Dependent care cost is estimated to range from 97 to 127 USD, with a maximum estimate of 246 USD (Figure 3). These calculations were based on a single dependent child under the age of 6 during standard hours (i.e., Monday to Friday, 8 AM to 5 PM), and does not account for care outside of standard hours; implicit in this calculation is the assumption that the student has a support network for unregulated, unpaid child-care (usually provided by family members) outside of standard hours. This estimate also does not account for specialized care for dependents with special needs, infants, multiple dependents, and elders. Despite efforts and improvements in gender equity and inclusion in the workforce, women are impacted disproportionately by dependent care obligations [23]. Although dependent care will often not be an issue for the average college student in the U.S.A., it will inordinately impact individuals from non-traditional backgrounds [24].

Costs of participating in field work will be unique to the individual and the support available to them; not all of these economic barriers are present for all. The overall cumulative costs associated with participating in a five-day field experience range from 1,697 to 2,601 USD; our estimates yield costs as high as 3,824 USD. However, individuals who are doing fieldwork for the first time or those who have other financial or familial obligations will incur greater costs (Figure 4). It is important to note that costs such as gear and flights are one-time purchases, the other factors will scale with the length of the field experience (e.g., meals and incidentals, lodging, loss of wages, and dependent care).

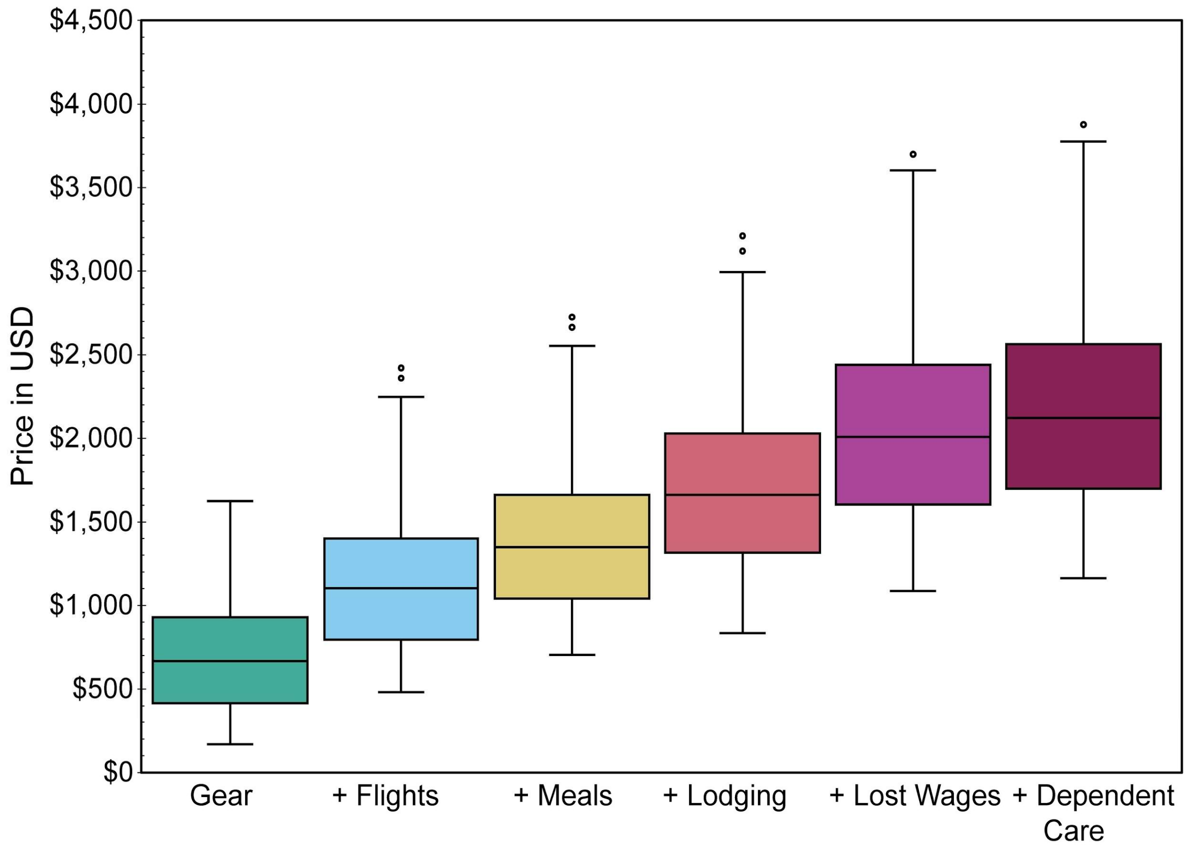

Figure 4: An illustration of how costs can have a cumulative and compounding impact, with each bar showing the burden of additional costs. Students who have to overcome multiple barriers to participate in the field may need to incur a prohibitively high cost. Dots denote observations outside of 2 standard deviations.

Conclusions

The expense of field education has been noted as a potential barrier to participation in geosciences; however, thus far, the primary focus of cost-assessments has been on the cost of conducting the science or the costs associated with tuition and fees. In the geosciences, we have historically neglected to account for and accommodate the financial costs associated with field activities, and the potential barriers to diverse participation that lie therein. Furthermore, objective data to assess how these burdens impact the persistence and retention of students in geosciences is largely absent. In this work, four major barriers have been identified that make access to field education challenging: (1) cost of personal field gear, (2) costs associated with travel and lodging, (3) loss of wages, and (4) costs of dependent care. All geoscience students need to have the financial and social capital to surmount at least one of these challenges (i.e., field gear); students from historically disadvantaged backgrounds (e.g., low-income groups, first-generation college students, historically excluded racial and ethnic groups, students who purchase women's and women's plus size clothing, students with disabilities) may need to overcome one or more of these financial challenges to participate in field experiences. These unacknowledged financial burdens perpetuate systemic bias against students who do not possess the necessary social and financial capital; ultimately, they contribute to the persistently low rates of representation of racial and ethnic minorities in geosciences. The information in this study is essential for educators, field team leaders and principal investigators designing budgets for inclusive field research or education in geoscience; accommodating these costs in research and education budgets would be a first step towards eliminating barriers to diverse participation. At the administrative level, the budgets for inclusive research, or required educational field experiences ***must*** account for the financial needs of individual student participants.

Unless we acknowledge and accommodate the costs of field work in research and education budgets, geosciences will continue to be a field in which only the financially and socially privileged can thrive.

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Methods

The costs associated with a five-day field experience trip which requires domestic travel were estimated for a field experience lasting one work week (a total of 5 days and 4 nights, including 3 workdays in the field). In this scenario, students worked in moderate temperatures and high humidity outside New Orleans, Louisiana, U.S.A., and were required to dig trenches, sample and describe deposits, collect ground penetrating radar, and work on a boat to collect cores and grab samples of flood deposits from Lake Pontchartrain.

The cost of field gear and travel were estimated using up to six major online retailers for each item (e.g., gear, flights, hotel bookings). Search results were sorted by "best match" or "featured" according to the retailers' algorithms (i.e., typically the default search settings). Research into typical consumer search behaviors (e.g., the average number of pages a consumer visits, the average time they spend on a website, and the average time spent making a purchasing decision) has shown that the first few pages (roughly 40-50 items displayed) is what most consumers use to inform their purchases of products, goods, and services online [25–28]. In our experience, the displayed items that were ranked lower than 40th on the list were no longer relevant to the search criteria. Therefore, the prices associated with the first 40 related items in the search were recorded.

Tracking online activity and prior search histories typically alter the prices displayed; this phenomenon is known as dynamic pricing. To account for this, each search was conducted after web browser history was cleared and a private browsing mode was used [29,30]. Dynamic pricing is usually set by prior search history and proprietary algorithm variations. As a result, collecting data on consumer price distributions poses a challenge. There are always slight variations in the price customers paid for an item [29]. The scope of this research is limited to assessing the scale of cost associated with participating in a field activity; we acknowledge that the nuances of proprietary internet algorithms and pricing may result in slight variability in the final estimate reached by different individuals with distinct browsing histories.

All prices associated with each specific item were used to estimate the range of costs associated with it. The 25th and 75th percentiles were used to bracket the estimated range of costs, as these represent the most likely cost incurred. The 95th percentile is also reported to show an estimated maximum value. These values were then totaled to compute the range of costs associated with a field experience and estimate the financial investment required from students.

Personal field gear: Items that were sold in sets of multiples were calculated by individual price per item and recorded in its place. Consumer products available are often marketed differently to men and women, mainly by altering minor aspects of the products such as cut, size variability, and color. Pricing of gendered items were compared, to assess whether men and women pay significantly different amounts [31]. The following gear had gender-related differences in pricing: hiking boots, raincoats, fast drying pants, wool socks, and work gloves. Three separate searches were conducted on each of these gear items: (1) a genderless search, (2) a search for women's gear, and (3) a search for men's gear. For example, when looking for data on hiking boots, three searches were performed – "hiking boots", "women's hiking boots", and "men's hiking boots". Pricing of standard size and plus sizes in women's rain wear, bras and pants were compared, to assess whether individuals buying gear in these different size categories pay significantly different amounts. The searches of the 7 retailers used in all the standard size gear searches yielded a population of plus size offerings that was half the size of the equivalent standard size populations (e.g., 80 plus size pants offerings compared to 167 standard size offerings). To account for the difference in sample size, 4 additional searches were conducted at plus size specific retail stores.

Cost of out of state travel: Cost analyses associated with domestic travel were performed for meals and incidentals, airfare, and lodging. Meals and incidental expenses were estimated using per diem rates determined by the United States General Service Administration. Per diem rates were calculated for 3 full days, and 2 half days associated with travel. Airfare and lodging estimates were determined by searching four major online travel booking agencies, 6 weeks ahead of the date of the search. A scenario in which students travelled from New Mexico, Ohio, and Georgia, USA, to New Orleans, Louisiana, USA, was used for airfare data. The price of the first top matches for airfare and travel bookings were recorded.

Lost wages: The United States' federal and state minimum wage laws (2020) were used to estimate the cost of lost wages. An 8-hour workday for 5 days was assumed while calculating the estimated loss of wages.

Dependent care: The average cost of childcare by state was used to compute a cost per week by state, and then to predict the range of costs associated with organizing childcare to attend a field trip [32]. This analysis was carried out for dependent care for a single child under the age of 6, under typical childcare conditions. These values could potentially be significantly larger as this approach does not account for special accommodations, price differences in adult dependent care, and availability of dependent care outside standard hours.

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