Mirroring minoritized students' cultures in Geoscience courses

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ABSTRACT

The use of active-learning strategies to teach out-of-school time (OST) geoscience courses has not significantly increased the number of racially minoritized students that pursue Geoscience. Studies hypothesize that significantly more minoritized students would pursue Geoscience if courses better resemble the students' Collectivist cultures. We test this hypothesis by using pre-course, post-course, and after-activity surveys to quantify minoritized student engagement, perception of, and interest in pursuing Geoscience during two OST courses taught with learning activities that emphasize Individualism (individual-learning) or Collectivism (group-learning). After-activity surveys show that minoritized students (n = 68) prefer group-learning activities. Students rated group activities as more difficult and fun. Students also believed they learned more during group-learning activities. Their engagement and interest in lessons varied more widely during individual-learning activities. Pre- and post-course surveys reveal that the number of students interested in pursuing STEM and Geoscience increased from 43 to 54 and 11 to 16, respectively. The students' perceptions of geoscientists broadened to include scientists who study not only the Earth but also its history and governing processes. We interpret these results to mean that (1) educators may employ group-learning activities when they desire to increase task difficulty without sacrificing student engagement, and (2) individual-learning activities are less reliable means of engaging minoritized students. Our results imply that incorporating more group-learning activities in the classroom and field may improve Geoscience diversity since group-learning activities resonate more strongly with minoritized students' cultures.

1 INTRODUCTION

Out-of-school time (OST) Geoscience courses have been locally successful at increasing the likelihood that minoritized students pursue STEM and Geoscience college degrees (Baber et al., 2010; Carrick et al., 2016; Wechsler et al., 2005). Researchers attribute these programs' successes to increased Geoscience visibility as a career choice, direct mentorship, and hands-on research experiences during formative years (e.g., Huntoon & Lane, 2007; Levine et al., 2007). Despite the local successes of some OST, a significant number of programs experience stagnation or limited success that prevent community-wide improvements in Geoscience diversity (Sidder, 2017). The reasons for the lack of larger-scale success are unclear but could be due to several intersecting factors. These include but are not limited to perceived disconnects Geoscience and marginalized communities' cultures, racism and microaggressions experienced by minoritized students in academia, marginalized communities' less favorable views of Geoscience compared to other careers (e.g., health sciences and engineering), a leaky pipeline, and prolonged lag-time between pre-college exposure and entry into professional Geoscience careers (Levine et al., 2007; Riggs & Alexander, 2007). This study's key goals are to explore the roles of pedagogy and culture on increasing recruitment of minoritized high school students. Understanding how this and other factors affect recruiting and retaining minoritized students is imperative since Geoscience remains one of the least ethnically and racially diverse STEM disciplines (Bernard & Cooperdock, 2018; Huntoon & Lane, 2007).

Typical Geoscience pedagogical techniques appear to resonate less with minoritized students' cultures, which could negatively impact students' experiences and perceptions of Geosciences (cf. Callahan et al., 2017; Weissmann et al., 2019; Wolfe & Riggs, 2017). Traditionally, Geoscience instructors mostly lecture and assess students via quizzes and tests.

These pedagogical techniques favor students from individualistic cultures, defined as cultures that emphasize individuated, linear, and faculty-oriented hierarchical perspectives of learning (Hall, 1989; Ibarra, 1999, 2001). Minoritized students more often grow up in collectivist cultures, which emphasize process-oriented and systems thinking, that individual efforts are not primarily for self-interest but for the success of the entire group, and which embody a desire to improve the community and/or society as a whole (Chavez & Longerbeam, 2016). Collectivist pedagogy thus emphasizes learning activities that require teamwork, group harmony, and emotional connection for success. The disconnect between minoritized students' cultures and individualistic academic culture may weaken minoritized students' sense of belonging and self-efficacy during science learning (e.g., Baber et al., 2010; Johnson et al., 2007), which are known to contribute to the leaky Geoscience pipeline (cf. Levine et al., 2007). An open question is whether transitioning from an Individualistic to Collectivist pedagogical model would increase minority student engagement and enthusiasm for Geoscience (cf. Weissmann et al., 2019; Wolfe & Riggs, 2017).

This pilot study tests the hypothesis that transitioning from traditional, Individualist learning to Collectivist learning in OST field- and classroom-based Geoscience courses increases minoritized students' engagement and interest in pursuing Geoscience. Our pedagogical reform draws from Astin's (1984) Inputs-Environment- Output (I-E-O) model, which posits that student Inputs (e.g., cultural upbringing, personal preferences, and tendencies) combined with a specific 'interventions' and/or Environments (e.g., an OST pre-college course) can produce desired outcomes (e.g., changes in career aspirations, perception of and/or interest in pursuing Geoscience). We used I-E-O to restructure two existing OST courses within the GeoFORCE Texas program and administered pre-course, post-course, and activity-specific surveys to test our hypothesis. Our qualitative and quantitative results show that minoritized students prefer group over individual-learning activities, group-learning activities are more reliable at engaging minoritized students, and difficult activities become more engaging when done in groups. Thus, our pilot study reveals a potential connection between students' cultures and self-assessed learning preferences, understanding, and interest in Geoscience. Ultimately, this is one small example of how pedagogical reform may contribute to diversifying Geoscience.

2 BACKGROUND

GeoFORCE has taught Geoscience to ~1800 Central and Southwest Texas students through week-long summer field-based courses since 2005. One of GeoFORCE's primary goals is to increase the number of minoritized students that enter Geosciences. Students enter GeoFORCE's program as rising high school freshmen and take GeoFORCE courses during the summer before each new school year. Even though GeoFORCE has increased the number of students pursuing STEM college degrees (e.g., 51% of college-enrolled alumni were STEM majors in 2017; GeoFORCE, 2017), the percentage of students pursuing Geoscience degrees has remained relatively low (e.g., 10% of STEM-enrolled students in 2017; compare with 14% enrolled in Biology; GeoFORCE, 2017). Our goal is to assess whether disconnects between the Geoscience pedagogy and minoritized students' culture could be related to why relatively few GeoFORCE students enter Geosciences.

Even though field-based courses are generally effective means of learning (Boyle et al., 2007; Elkins & Elkins, 2007), minoritized students could be deterred by the outdoor component of Geoscience learning since they are less likely than their white peers to report enjoyment of outdoor activities like hiking and camping (Whitney et al., 2005). Minoritized students are also more likely to negatively associate outdoor work with laboring (Seymour & Hewitt, 1997). This scenario illustrates the influence of cultural values and socialization as components of the 'Geoscience Pipeline' (Levine et al., 2007) that influence the likelihood of minoritized students entering and staying in Geoscience professions (cf. Seymour & Hewitt, 1997).

Researchers suggest two strategies for reducing the disconnect between minoritized student culture and learning environment. Firstly, as opposed to traditional lecturing and quiz-and-test assessment, active-learning strategies have been shown to significantly improve retention and engagement and deepen STEM interest for minoritized students (Graham et al., 2013; Sherman-Morris & McNeal, 2016; Tsui, 2007). Secondly, several previous OST courses have had great success engaging minoritized students by teaching in a culturally-situated context, thus making Geoscience more relevant, relatable, and inclusive for minoritized learners (Apple et al., 2014; Brown et al., 1989; Riggs & Alexander, 2007; Unsworth et al., 2012). For example, Semken (2005) demonstrated that Place-Based Learning, which synthesizes local cultural knowledge, builds student confidence in 'thinking like a geoscientist' and makes it easier for students to see themselves as professional Geoscientists (see also Hanks et al., 2007; Pandya et al., 2007). Furthermore, Tewksbury (1995) taught an introductory-level, classroom-based geology class on modern Africa, connecting its geology to its prehistoric, historical, political, and economic evolution. This course enrolled 11 African American students, which represented more than one-sixth of her university's African American enrollment at the time. Thus, active learning and culturally-situated learning positively impact minoritized student learning. This lead us to hypothesize that blending both strategies would positively impact minoritized student learning, engagement, and interest in STEM.

3 STUDY PARTICIPANTS

Our study population includes sixty-five rising eleventh (40 students) and twelfth-grade (25 students) students in two of GeoFORCE's OST courses. All students live in underserved communities and/or attend minority-majority high schools in Texas. The students are 56% women, 44% Black or African American, 12% Asian or Pacific Islander, 36% Hispanic or Latinx, and 8% white. Fifty-six percent of these students have at least one parent with a four-year college degree. Ninety-six percent of the students previously took a science course taught using active-learning pedagogy (Fig. 1).

Educational and coordination staff facilitated student learning. Educational staff (3-5 individuals) included (1) an instructor who was responsible for course content, design, and pedagogy and (2) two educational coaches (ECs) who primarily assist with pedagogy. The twelfth-grade academy also employed two teaching assistants named Educational Coaches in Training (ECITs). Instructor-to-student ratios were 1:13 and 1:5 in the eleventh and twelfth-grade academies, respectively. Two coordination staff members executed field trips and classroom logistics; one person obtained supplies.

The educational and coordination staff reflected the students' racial and ethnic diversity. The course instructors are the authors of this paper and were late-career Ph.D. students when they taught the courses. The eleventh-grade instructor is a white woman and a Structural Geology Postdoctoral Researcher. The twelfth-grade instructor is a black man and Geophysics Postdoctoral Investigator. The eleventh-grade academy ECs were one Geocognition (white male) and one Geology (multi-ethnic Hispanic-American male) Ph.D. student. The twelfth-grade academy ECs were a mid-career high school science teacher (Latina) and a Geology Ph.D. student (Asian-American woman); the ECITs were two undergraduate STEM pre-service teachers (a Latina and a black woman). The coordinators were the same for both academies, one Latino and one white woman.

4 RESEARCH DESIGN AND METHODS

We used pre-trip and post-trip surveys to assess student learning preferences and interest in lessons taught with active-learning strategies that emphasize Individualism or Collectivism. We used after-activity surveys to evaluate the students' engagement (i.e., fun and excitement), interest in, and perception (i.e., difficulty and understanding) of the learning activities and Geoscience. We statistically analyze the surveys with means, standard deviations, correlation coefficients, and T-tests. We conducted this research with Institutional Review Board approval from the University of Texas at Austin.

4.1 Course Design and Structure

We categorized learning activities as individualistic, intermediate, and collectivist, rated from 1 to 10, where 1 is extremely individual, and 10 is extremely collectivist. Individualistic learning activities included lecturing, single-person active-learning activities (e.g., concept sketching), and quizzes. Intermediate activities included workshops -- i.e., guided inquiry, hands-on, group activities that access affective learning domains and stimulate critical thinking through skill-building. Intermediate activities introduced new concepts and themes and were a mixture of student-driven and instructor-guided learning. Collectivist activities included societally relevant challenge-based field tasks that apply critical thinking skills and content learned during workshops and/or synthesis projects that take 3-5 days to solve and emphasize teamwork. Collectivist activity problem-solving was dominantly student-driven.

4.1.1 Eleventh-grade Pacific Northwest Academy

The eleventh-grade academy taught students Plate Tectonics, earthquake and volcano hazards, and the formation of modern sedimentary depositional environments in Oregon and Washington. Previous GeoFORCE students who completed four years of lecture-based, quiz-and-test assessment (i.e., traditional) Academies reported that the Pacific Northwest Academy was their favorite because of the beautiful landscapes and volcanoes. Instructors taught this cohort's course using a "slow-release" active-learning strategy (Fig. 2A). Most activities during the first three days included "individualist" lecturing and "intermediate" workshops. The activities became more "collectivist" and more difficult during days 4-6. "Individualist" and "intermediate" activities prepared students for the more challenging "collectivist" activities.

Eleventh-grade instructors taught most of the course using classroom- and field-based guided inquiry, in which instructors chose topics and questions and students designed products and solutions. For example, during one series of workshops, students drew concept sketches of volcanoes while instructors guided them through discussion of similarities and differences in formations and functions between 'end-member' volcanoes; students identified minerals and igneous rocks; and students performed experiments to learn about viscosity using 'lavas' of different 'compositions' (e.g., water, olive oil, honey, mayonnaise). Students then used their knowledge in the field, where instructors tasked them with reconstructing how quickly a Cascade porphyritic andesite from Mount Hood cooled, what the magma's composition was that formed the rocks, and how explosive the eruption likely was. The eleventh-grade course also incorporated one multi-day (days 4-6) activity where teams of 5-6 students conducted synthesis projects related to "The Rock Cycle" or "Natural Hazards." The form and medium of the synthesis project were left entirely up to the students; products included an anthropomorphized skit of the rock cycle, hand-drawn annotated and narrated videos (e.g., “Moovly” or “Whiteboard Animations”), and a news broadcast complete with interviews with “local geology experts.”

4.1.2 Twelfth-grade Central Texas Academy

The twelfth-grade academy taught students the geologic history of Central Texas while emphasizing the effects of tectonism, volcanism, erosion, water, and biological life on landscape evolution. Instructors taught using the STAR Legacy Cycle (Bransford, 2017), following a curriculum developed specifically for the GeoFORCE twelfth-grade academy (Ellins et al., 2018; Thomas et al., 2018; Kotowski et al., 2018). The Legacy Cycle includes six learning stages referred to as (1) the challenge, (2) generating ideas, (3) gaining multiple perspectives, (4) researching and revising, (5) assessing, and (6) going public (Fig. 2B). Twelfth-grade instructors taught each Legacy Cycle stage using hands-on active learning workshops, lectures, and guided inquiry field activities. During the challenge stage, instructors presented students groups with a practical (i.e., real-life applicable) problem to solve -- i.e., (1) designed Snapchat filters to entice 18-to-34-year-olds to visit and learn the geologic history of six Central Texas national parks or (2) conducted background geologic work for Google Sustainability who wants to evaluate the impacts of human development on landscape and water resources in Central Texas before building a new Google campus in Austin. The generating ideas stage is where instructors provided the background information needed to accomplish the challenge. The gaining multiple perspectives stage is where instructors introduced students to external resources and technology to supplement learning. Students designed the methods required to solve the challenge during the research and revise stage. Students collected new data, made independent observations, and drew interpretations during the three stages described above. The instructional staff facilitated this by fielding questions, redirecting off-topic efforts, and correcting student mistakes through group discussions. In the assessment stage, students tested their designed methods. Students presented their work to an audience of fellow students, educational and coordination staff, invited experts, and the general public during the going public stage. Students generally progressed through each successive stage of the cycle with time (e.g., day 1-7). Earlier stages were revisited as instructors and students deemed necessary; the larger cycle thus contains smaller, embedded cycles of active learning (Fig. 2B).

4.2 Survey Types and Assessment Strategies

We announced the research goals before administering the pre-course, post-course, and after-activity surveys (see Table 1). Student survey participation was optional, and responses were anonymous. The total number of pre- and post-survey responses are not the same (eleventh grade: 40 pre, 35 post; twelfth grade: 25 pre, 22 post) because some students did not respond to the post-course survey.

Pre- and post-course surveys solicited student demographic data, life experiences, learning preferences, previous academic backgrounds, career aspirations, and perceptions of science and Geoscience. The surveys requested free-form, Likert-scaled, and/or multiple-choice answers. Students filled out the pre- and post-course surveys on the first day and within 1-2 days after the courses ended, respectively. Both surveys asked the same questions.

The after-activity surveys assess student engagement and interest during learning-activities. These surveys solicit free responses to “the main thing I had to do today was” and ask students to rate (from 1 to 10) their interest in learning more about a topic, how well they believed they understood topics, and how difficult, exciting, and fun topics were. Students mainly completed these surveys within 24 hours after each activity, either while traveling, in classrooms, or at the end of the day. We designed these surveys to be completed in five minutes.

We used pre-course, post-course, and activity-specific surveys to assess changes to the students' (1) perception of science and Geoscience, (2) interest in pursuing STEM and Geoscience, and (3) preference for individual versus group activities. We calculated means and standard deviations for Likert-scaled answers. We used Welch's T-test to determine whether there were statistically significant changes in responses to the pre- and post-course survey questions. We denote p-value, t-statistics, and degrees of freedom from the T-tests with acronyms *p*, *t*, and *df*, respectively. We performed correlation coefficient analyses between all variables and used indexing and qualitative description analysis (QDA) to identify commonly used descriptors and themes within free response answers (cf. Libarkin & Kurdziel, 2002).

5 RESULTS

Survey data demonstrate that the students prefer learning in groups, regardless of the tasks' difficulties. Results from both academies are mostly similar. We combine and present the survey data together, and we highlight notable differences.

5.1 Student learning preferences

Pre- and post-course surveys reveal that the course influenced the students' preferences for group, hands-on, and individual-learning. Students' preference for individual learning decreased ($p = 0.0025$, $t = 3.10$, $df = 97.80$) while their preference for group learning slightly increased ($p = 0.34$, $t = -1.00$, $df = 117.00$). The students' confidence in public speaking and how much they like lectures increased ($p = 0.0006$, $t = -3.52$, $df = 117.99$ and $p = 0.008$, $t = -2.70$, $df = 118.29$, respectively) (Fig. 3A). Student preference for hands-on activities and group projects was roughly the same in pre- and post-course surveys (i.e., ~8/10) ($p = 0.58$, $t = 0.56$, $df = 115.50$ and $p = 0.68$, $t = 0.42$, $df = 11.38$, respectively). The students' free-form answers revealed that they believed group workshops prepared them relatively well for field activities.

5.2 Student engagement during individual- vs. group-learning activities

Students felt they learn more as the lessons become more exciting, fun, and interesting. High positive correlations ($r^2 > 0.7$) exist between (1) the students' interest in learning more about a topic and their perception of how much fun they had learned and (2) how fun and exciting they thought topics were (Fig. 3B). Moderate positive correlations ($r^2 = 0.5\text{-}0.6$) exist between (1) interest in learning more about topics and how exciting they believe topics were, and (2) how much fun they thought they had and their interest in learning more about topics (Fig. 3B). A low positive correlation ($r^2 < 0.4$) exists between interest in learning more about a topic and the students' perceived understanding. The students' perception of the difficulty of learning activities moderately anti-correlates their interest in learning more about the topics (Fig. 3B). No significant correlation exists between the students' perceived difficulty of learning activities and how much fun students believed the activities were. In general, correlations between students' perceived understanding, interest, fun, and excitement are stronger for group versus individual-learning activities.

5.3 Evolution of students' perception of Geoscience and career aspirations

Indexing and QDA of student responses provide insights into the students' view of scientists and Geoscience careers. Student responses to 'describe a scientist in three words' demonstrate that students primarily believe that scientists are smart, intelligent, curious, hard-working, and creative. Problem-solve, discover, and study were the students' three most commonly used verbs to describe what scientists do. The frequency of mentions of these three words was roughly the same in pre- and post-surveys (see appendix A). While describing a Geoscientist's job, students' use of 'process' increased from one to seven times in pre- and post-surveys, respectively (Table 2). Other used process-oriented verbs and descriptors include ‘function,’ ‘Earth’s history and its formation’, and ‘how landforms are shaped.’ The number of students mentioning ‘rocks’ on pre- and post-course surveys was 24 versus 11, respectively. The percentage of students indicating that they will pursue a non-geoscience STEM major and Geoscience in college before and after the course increased from 69 to 93% and 15 to 27%, respectively (Fig. 5). The number of students interested in pursuing Geoscience rose from 4 to 10 and from 2 to 4 in the eleventh and twelfth-grade courses, respectively.

6 DISCUSSION AND IMPLICATIONS

Our primary interpretations are that (1) students prefer collectivist active-learning activities and (2) culturally-situated pedagogical approaches may improve Geoscience diversity. Our sample size is relatively small (65 students). Additional studies are thus needed to test the robustness of these findings.

6.1 Students prefer active learning that emphasizes Collectivism

Students prefer active-learning activities that emphasize Collectivism. This is supported by the observations that students consistently (1) rated active group-learning exercises as the most exciting, interesting, and fun activities (cf. Fig. 3B) and (2) remained more engaged (e.g., excited, interested, and had more fun) during the most difficult active-learning group activities (cf. Fig. 3B, see colored circles in ‘difficulty vs. interest’ and ‘fun vs. difficulty’). We also interpret that active-learning group activities are more reliable at engaging students because the standard deviations for moderate and strong correlations in group-activity data are smaller than in individual active-learning activities.

Since our active learning exercises were completed in student groups and were presented as challenges with societal relevance, this work suggests that active learning impacts may be amplified when executed in a culturally-situated framework (cf. Lee & Fradd, 1998). This inference is supported by observations that group activities show moderate positive correlations between engagement metrics (e.g., interest, excitement, and fun) and perceived understanding. Thus, instructors can increase tasks' difficulty without sacrificing engagement or their perceived understanding when students work in groups. The students' strong preference for hands-on workshops and group-learning demonstrates that more difficult group activities are no less engaging or challenging to understand according to students' perception of their own learning compared to individual activities that may seem easier to do. Active learning has been suggested as a useful tactic to improve recruitment and combat attrition of minoritized students in STEM disciplines (Graham et al., 2013; Tsui, 2007); we suggest that the intersection of active and culturally-situated learning may amplify the positive impacts of both strategies (e.g., Fig. 6).

6.2 Can culturally-situated group-learning improve Geoscience diversity?

Our study suggests that mirroring minoritized students' cultures in Geoscience courses can improve student engagement, broaden their perceptions of Geoscience, and increase their interest in pursuing STEM and Geoscience in college. Comparing pre- and post-survey free responses of a geoscientist's job description, the increased occurrence of process-oriented terms and decreased occurrence of the narrowed view that a geoscientist "studies rocks" is particularly noteworthy. The changes to the students' perception of scientists and geoscientists likely occur for several reasons. Chief amongst them are subject matter, hands-on activities, group-learning projects, and what the instructors emphasize during the courses. However, both GeoFORCE cohorts exhibited similar perception changes, despite focusing on very different topics and themes. Therefore, we tentatively rule out the possibility that specific course content led to a more process-oriented view. The focus on a process-oriented view of Geoscience aligns with aspects of high-context, Collectivist cultural ideals (Chavez & Longerbeam, 2016; Ibarra, 1999), which we interpret to be the most likely cause of the increased interest and broadening of students' perspective.

The increase in the number of students who want to pursue STEM, and Geoscience specifically, is a significant improvement compared to GeoFORCE statistics as a whole. Before implementing the Legacy Cycle model with the twelfth-grade academies in 2018, all GeoFORCE courses were taught using a traditional, lecture-based, and quiz-and-test-assessment approach. For a rough comparison, in 2017, 51% of all college-enrolled GeoFORCE alumni were STEM majors, and of that sub-group, 10% had declared Geoscience majors (GeoFORCE, 2017). Compare these percentages with our small study population, which reported increased interest in pursuing STEM, up from 69% (pre) to 93% (post), and Geoscience, up from 15% (pre) to 27% (post). The only programmatic difference between our study population's experience and previous GeoFORCE students' is our pedagogy. Therefore, we attribute these evolutions to our culturally-situated pedagogical shift.

The call to rebuild OST pedagogical foundations for programs like GeoFORCE around student identities, cultures, and worldviews is supported by recent research addressing the sociological, psychological, and socio-economic 'whys' that can explain some diversity programs' successes (cf. Callahan et al., 2017; Riggs & Alexander, 2007; Lave and Wenger, 1991; Weissmann et al., 2019; Wolfe & Riggs, 2017). Furthermore, previous efforts to incorporate culturally-situated teaching have had noteworthy success and promise to improve community diversity. For example, Semken (2005) demonstrated that Place-Based Learning that synthesizes local cultural knowledge builds student confidence in 'thinking like a geoscientist,' making it easier for students to potentially see themselves filling professional Geoscience roles (see also Hanks et al., 2007; Pandya et al., 2007; Tewksbury, 1995). Furthermore, culturally-situated learning can increase students’ sense of belonging (Moore, 2020), which is yet another ‘valve’ along the Geoscience pipeline. Our study thus lends credence to previous work that highlights the benefits of deemphasizing Individualism and Western academic linearity and competition, in favor of group and community membership, the interconnectedness of scientific cycles and processes, teamwork, and practical problem-solving for community betterment (Seymour & Hewitt, 1997; Weissmann et al., 2019; Wolfe & Riggs, 2017). As educators, we can take small steps in our field- and classroom-based courses towards a systemic climatic shift that better resonates with our minoritized students’ cultural values. Our small-scale study serves as motivation for more extensive (in regards to the number of participants) and targeted (in development of culturally-situated activities and survey questions) studies addressing how to best employ culturally-situated learning tools to improve Geoscience diversity.

6.3 Limitations of the present study and future research directions

Our study’s primary assumption is that the students, being >50% women and >50% Hispanic, Latinx, and Black, identify with Collectivist cultures. We make this assumption because research shows that women and ethnically and racially minoritized students primarily identify with Collectivist cultural ideals (Chavez & Longerbeam, 2016; Ibarra, 1999, 2001). The students within this study likely embody a spectrum of cultural beliefs and life experiences that expand beyond Collectivism (cf. Gudykunst et al., 1996). However, our pre- and post-survey data support that, on average, these students prefer learning styles that are group-focused and societally-relevant. Therefore, the assumption that these students identify more with Collectivism is likely valid for this pilot study. Further research is needed to characterize the relationship between student cultural identity and learning preferences. In reality, a Multicontext and/or blended approach will likely produce the most effective, engaging, and inclusive learning environment (e.g., Weissmann et al., 2019; Fig. 6).

Our study does not have a control group because COVID-19 is real and prevents additional in-person work. One way to introduce a control group is to distribute identical pre-, post-, and activity-specific surveys to separate cohorts that experience the traditional versus culturally-situated approach in the same field location; the sane educational team should teach the courses. Control groups will be crucial in defining what aspects of the GeoFORCE 'intervention,' i.e., the 'Environmental' aspect of the I-E-O model, are controlling Outputs (i.e., changes in student perception and engagement) (Astin, 1991).

Field locations may influence student engagement and enthusiasm in ways that we did not quantify. Since many GeoFORCE alumni report that the eleventh-grade Pacific Northwest trip to be their favorite, the greater increase in reported interest in pursuing Geoscience in eleventh-grade students may reflect this partially. However, student interviews from past academies suggest a common motivation to participate in GeoFORCE is to apply acquired knowledge and skills to understand Earth in 'their own backyards.' This indicates that a connection to place may elevate student experience in the twelfth-grade academy (Hanks et al., 2007; Semken, 2005; Semken et al., 2017). Lack of substantial differences in the evolution of student learning preferences supports our interpretation that changes in student learning preferences and perception of Geosciences arose mainly from the pedagogical shift, not just because students were exposed to new and exciting places (e.g., the Pacific Northwest). Future targeted evaluations assessing the impact of course location should nevertheless be conducted to determine the influence of connection to place and other external factors on minoritized student interest in the Geosciences.

7 CONCLUSIONS

This study assesses whether racially minoritized students become more engaged and interested in pursuing Geoscience when instructors teach in ways that resemble these students' cultures more closely. Pre-course, post-course, and after-activity surveys reveal that minoritized students within two (one eleventh- and one twelfth-grade) academies in GeoFORCE's out-of-school-time program become more engaged during active-learning activities that emphasize hands-on and group-learning versus individual-learning activities. By the end of the courses, students' perception of Geoscientists broadened from someone who studies not only the Earth but also its governing processes. This broadening of student perception is likely related to the students' exposure to diverse people, technology, resources, and problem-solving methods during the courses. The number of students considering majoring in Geoscience in college increased from 25 to 55% by the end of the course.

Future studies should investigate if and to what degrees the intersection of active learning and culturally-situated learning influences minoritized students' perception of and interest in pursuing Geoscience. We recommend increasing our sample size, adjusting Collectivist pedagogy to more closely resonate with minoritized students' upbringing, culture, and life experience, and testing whether Collectivist pedagogy is beneficial to other students that identify with high-context lifestyles (e.g., women and Indigenous people). By teaching in ways that better resemble minoritized students' cultures, Geoscience can make incremental steps to improving belonging, accessibility, justice, equity, diversity, and inclusivity (Be A JEDI).

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Figure and Table Captions

Figure 1. Combined student demographics from eleventh- and twelfth-grade GeoFORCE Academies. From left to right, pie charts show a break-down of student gender identity, ethnicity, and proportions of first-generation college students (i.e., students who do not have at least one parent that received a 4-year college degree).

Figure 2. Schematic illustrations of contrasting instructional styles. (A) The eleventh-grade course used a ‘slow release’ approach that gradually transitioned from traditional individual learning (e.g., lectures) to active group learning (e.g., workshops and field challenges) through time. (B) The twelfth-grade course used a modified STAR Legacy Cycle; the entire course revolves around an overarching week-long challenge and embeds smaller blended learning cycles (i.e., lectures, workshops, and mini-challenges) throughout the week (Ellins et al., 2018).

Figure 3. (A) Student learning preferences from pre- and post-course surveys (light and dark grey, respectively). White circles are result averages, and error bars are 1-sigma standard deviations. (B) Self-assessed student learning experiences from activity-specific surveys. Data points are averages of 25-40 individual student survey responses. The r^2 values are provided for all data (r^2), individual activities only (r_i^2), and group activities only (r_g^2). See text for a discussion of results. AC11: eleventh-grade academy; AC12: twelfth-grade academy.

Figure 4. Word clouds depicting students’ perception of a “geoscientist’s job description.” The word sizes scale with the number of times it appeared in student responses, reflecting emergent themes and common perceptions. The same data are shown in Table 2.

Figure 5. Evolution of student interest in pursuing STEM and Geoscience college degrees from pre- and post-trip surveys. Note that in the post-trip surveys, ‘unsure’ was not provided as an option.

Figure 6. Venn Diagram illustrating the ideal environment to engage diverse students in STEM and Geoscience courses is to blend active-learning and culturally-situated learning in the classroom and field.

Table 1: Selected pre-trip, post-trip, and activity-specific survey questions and prompts. Results of these questions are presented and discussed in this study. The type of data acquired for each question or prompt is shown in the left column (i.e., numerical data on a Likert scale, where 10 is most strongly agree or prefer; Yes/No/I don't know; free response). For a full list of pre- and post-trip survey questions, please see the Appendix.

Table 2: Word count from pre- and post-trip survey prompt: "a geoscientist's job description." Data are plotted in word clouds in Figure 4.

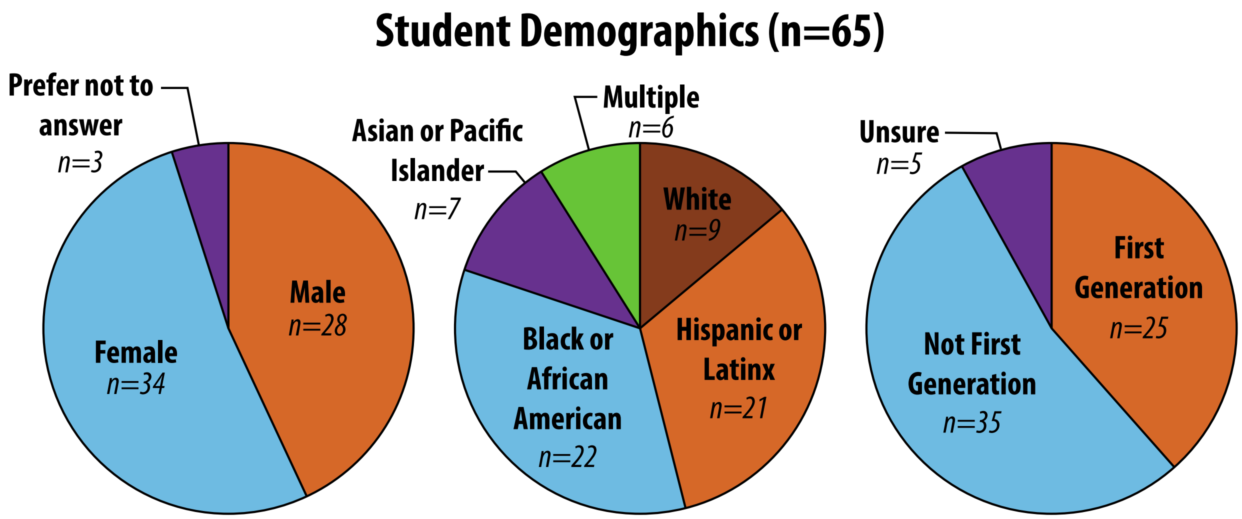
Student Demographics (n=65)
Prefer not to answer
n=3
Male
n=28
Female
n=34
Asian or Pacific Islander
n=7
Multiple
n=6
White
n=9
Hispanic or Latinx
n=21
Black or African American
n=22
Unsure
n=5
First Generation
n=25
Not First Generation
n=35

Figure 1

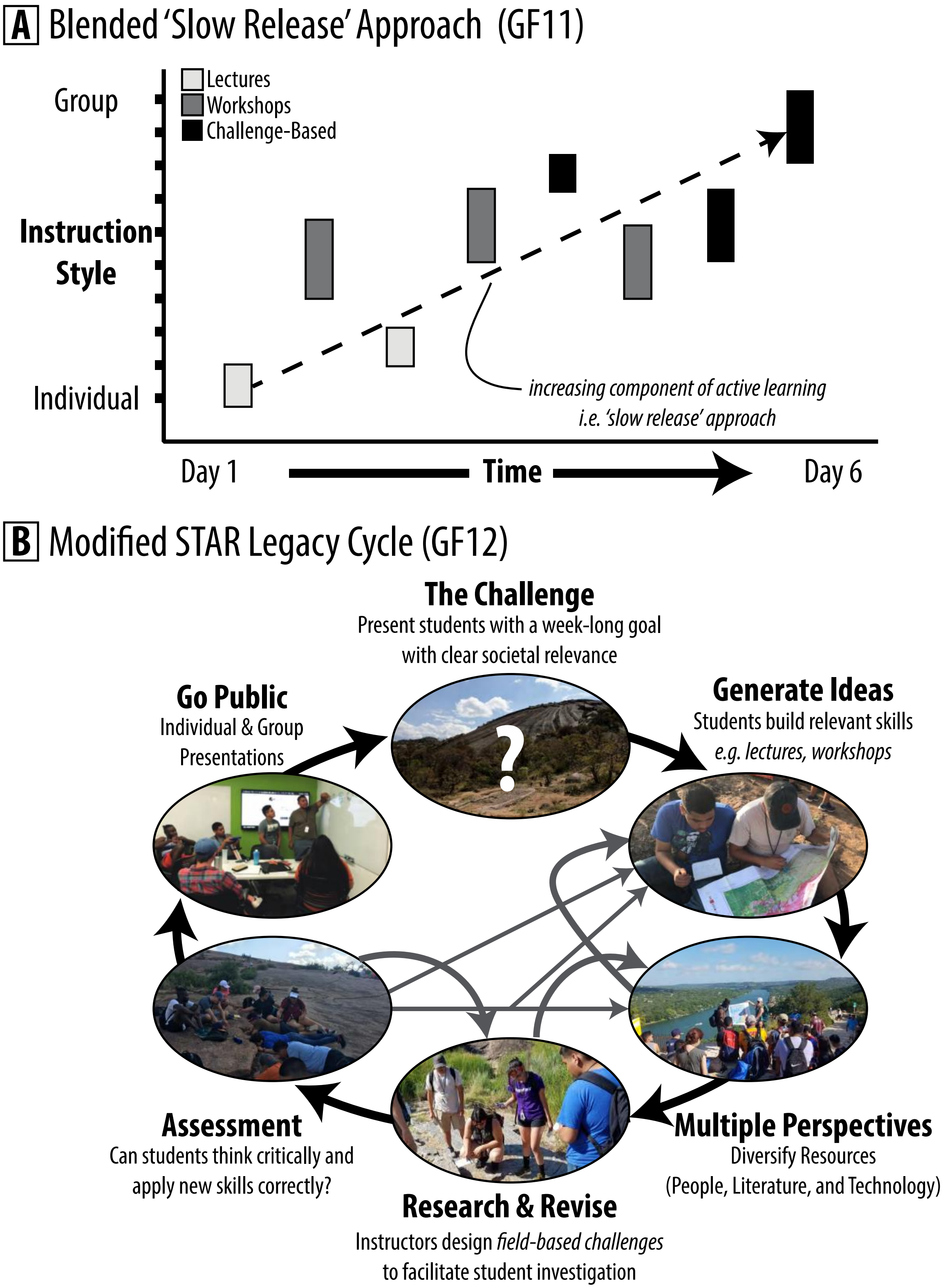
A Blended 'Slow Release' Approach (GF11)
Group
Instruction Style
Individual
Lectures
Workshops
Challenge-Based
increasing component of active learning
i.e. 'slow release' approach
Day 1
Time
Day 6
B Modified STAR Legacy Cycle (GF12)
The Challenge
Present students with a week-long goal
with clear societal relevance
Generate Ideas
Students build relevant skills
e.g. lectures, workshops
Multiple Perspectives
Diversify Resources
(People, Literature, and Technology)
Research & Revise
Instructors design field-based challenges
to facilitate student investigation
Assessment
Can students think critically and
apply new skills correctly?
Go Public
Individual & Group
Presentations

Figure 2

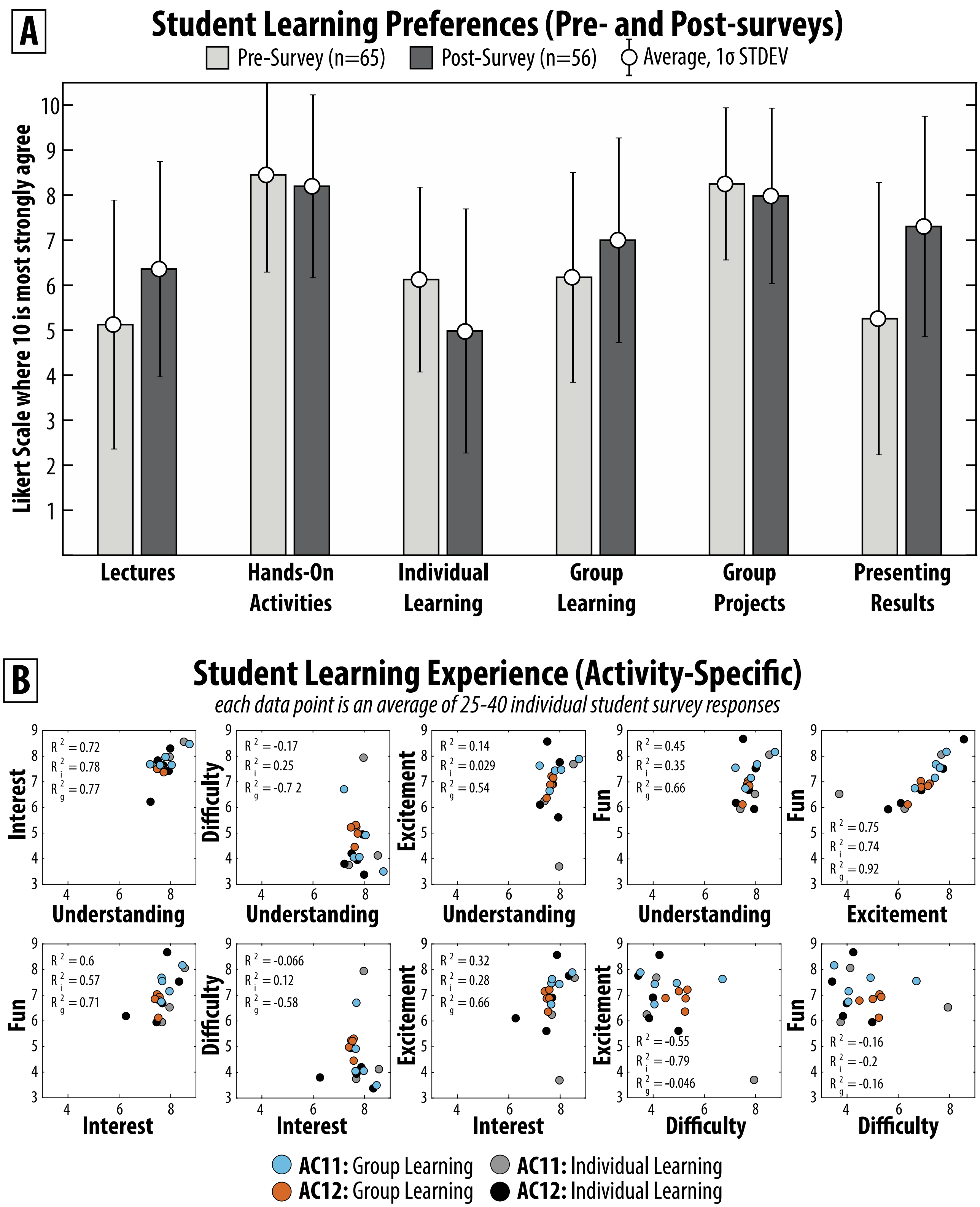
A
Student Learning Preferences (Pre- and Post-surveys)
Pre-Survey (n=65)
Post-Survey (n=56)
Average, 1σ STDEV
Likert Scale where 10 is most strongly agree
Lectures
Hands-On Activities
Individual Learning
Group Learning
Group Projects
Presenting Results
B
Student Learning Experience (Activity-Specific)
each data point is an average of 25-40 individual student survey responses
Interest
Difficulty
Excitement
Fun
Understanding
Excitement
Interest
Difficulty
AC11: Group Learning
AC11: Individual Learning
AC12: Group Learning
AC12: Individual Learning

Figure 3

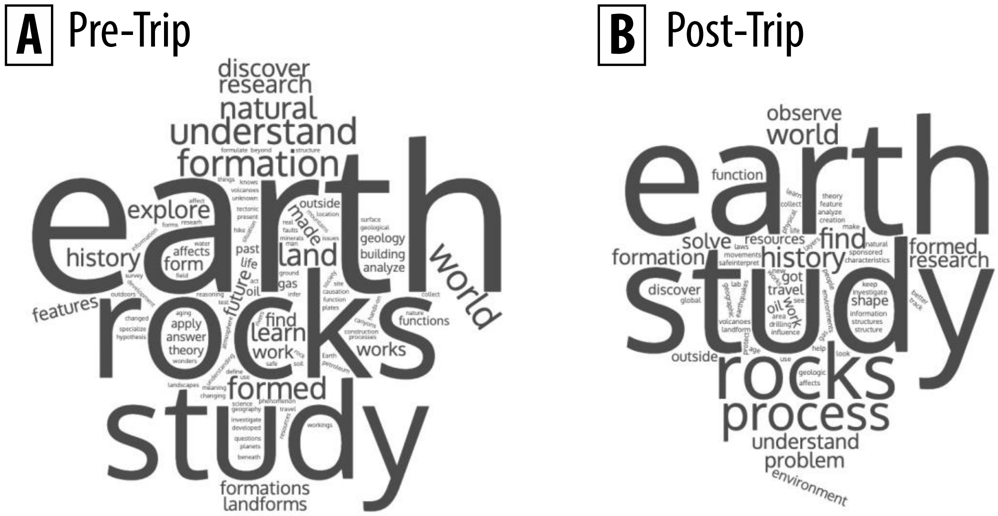

Figure 4

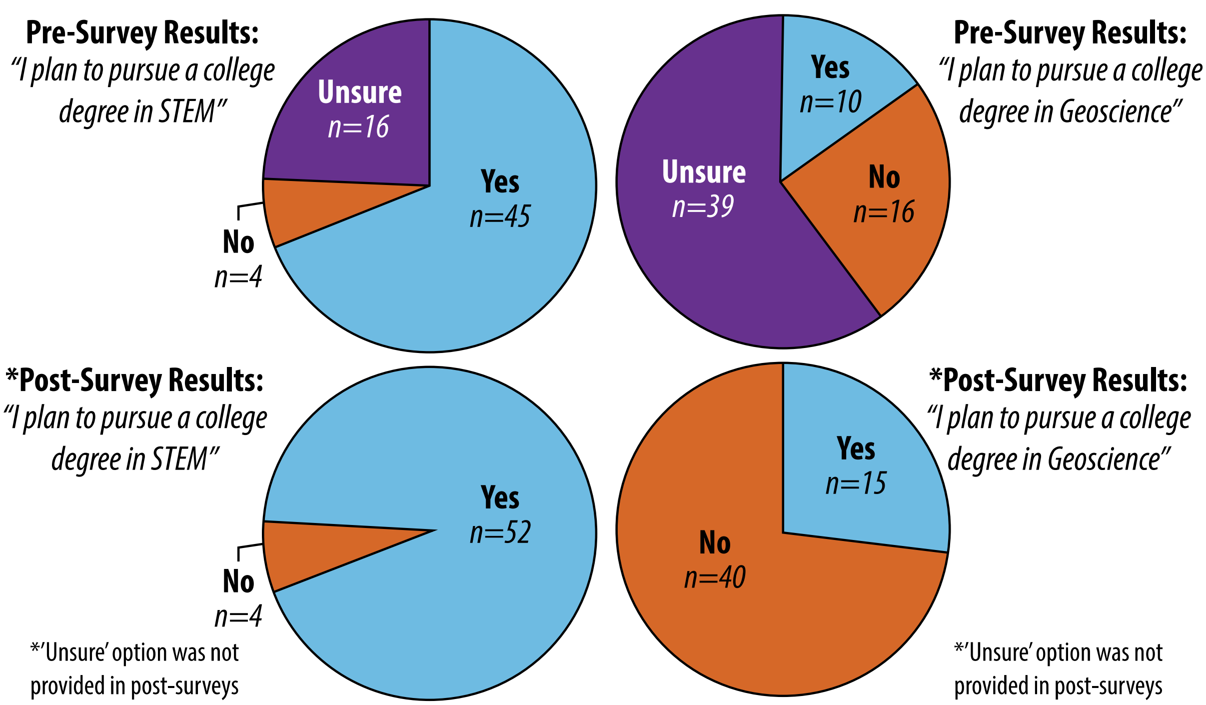

Figure 5

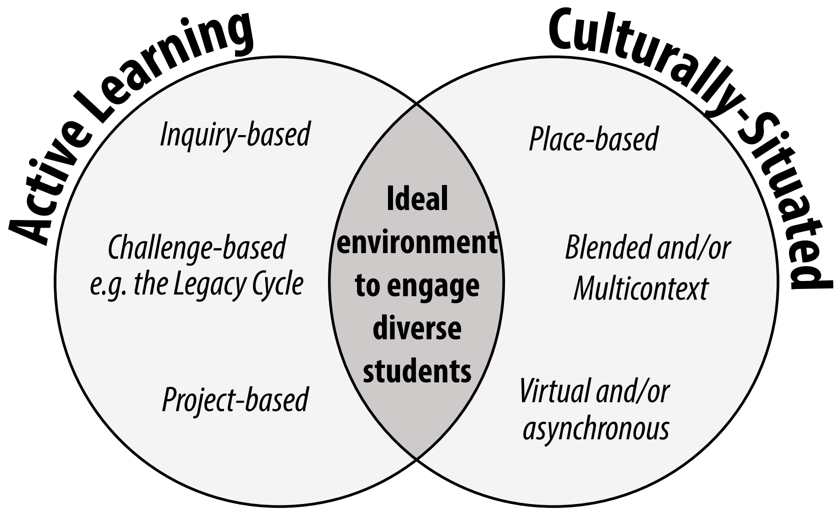
Active Learning
Culturally-Situated
Inquiry-based
Challenge-based
e.g. the Legacy Cycle
Project-based
Ideal environment to engage diverse students
Place-based
Blended and/or
Multicontext
Virtual and/or
asynchronous

Figure 6

PRE-TRIP LEARNING PREFERENCES	
Likert 1-10	I enjoy listening to lectures.
Likert 1-10	I enjoy hands-on activities in the classroom and/or outside.
Likert 1-10	I feel like I learn the most when I listen to lectures.
Likert 1-10	I feel like I learn the most when I read textbooks.
Likert 1-10	I feel like I learn the most when I do labs and hands-on activities.
Likert 1-10	I enjoy expressing creativity in the classroom.
Likert 1-10	In general, I believe that my test and quiz scores are a good reflection of what I know and what I can do.
Likert 1-10	In general, I believe my best work is done individually.
Likert 1-10	In general, I believe my best work is done with a partner or small group.
Likert 1-10	Doing a week-long GeoFORCE project with a team of students sounds like a lot of work and I do not want to do that.
Likert 1-10	Doing a week-long GeoFORCE project with a team of students sounds fun, and I would like to do that.
Likert 1-10	I find studying for and taking quizzes and tests rewarding and fulfilling.
Likert 1-10	I find giving oral presentations and talking in front of my peers rewarding and fulfilling.
Likert 1-10	I feel like I have learned a lot from my GeoFORCE classes about how the Earth works.

POST-TRIP LEARNING PREFERENCES	
Likert 1-10	This week on the GeoFORCE trip, I feel like I learned the most from listening to lectures.
Likert 1-10	This week on the GeoFORCE trip, I felt like I learned the most by doing hands-on activities in the classroom and/or outside (think of the "workshops").
Likert 1-10	This week on the GeoFORCE trip, I enjoyed activities where I had to figure things out, answer questions, and think like a scientist.
Likert 1-10	I enjoyed the evening workshops and felt prepared for the next day.
Likert 1-10	I liked evening workshops better than evening lectures.
Likert 1-10	I enjoyed giving pop-up presentations and thought it was a good way to practice talking in front of my peers and reinforce concepts we learned that day.
Likert 1-10	I think pop-up presentations are stressful.
Likert 1-10	I think pop-up presentations are a waste of time.
Likert 1-10	This past week, I feel like my best work was done individually.
Likert 1-10	This past week, I feel like my best work was done with a partner and/or a small group.
Likert 1-10	Doing a week-long GeoFORCE project with a team of students sounds like a lot of work and I do not want to do that.
Likert 1-10	Doing a week-long GeoFORCE project with a team of students sounds fun, and I would like to do that.

PRE- AND POST-TRIP FUTURE PLANS AND PERCEPTIONS	
Yes/No/I don't know	I plan to pursue a degree in science, technology, engineering or math.*
Yes/No/I don't know	I plan to pursue a degree in the geosciences.*
Free response	In three words, describe a "scientist"
Free response	In a brief sentence or two, describe what a scientist does.
Free response	Briefly describe your idea of a geoscientist's job description.

ACTIVITY-SPECIFIC SURVEY QUESTIONS AND PROMPTS	
Free response	The main thing I had to do and/or produce today was:
Free response	Any comments?
Likert 1-10	How much do you feel like you understood the material in this activity?
Likert 1-10	Are you interested to know more about the topics in this activity?
Likert 1-10	How difficult was this activity/task?
Likert 1-10	How exciting and fun was this activity/task?

Table 1

Your version of a "Geoscientist's Job Description"

Pre-Trip Survey						Post-Trip Survey			
35	earth	**1**	act	**1**	phenomenon	**23**	earth	**1**	gas
25	rock(s)	**1**	affect	**1**	planets	**22**	study	**1**	geographic
22	study	**1**	aging	**1**	plates (tectonic)	**11**	rock(s)	**1**	geologic
9	formation (rock unit)	**1**	atmosphere	**1**	present	**7**	process	**1**	global
6	understand	**1**	beneath	**1**	processes	**4**	find	**1**	help
6	world	**1**	beyond	**1**	questions	**4**	history	**1**	influence
6	work(s) (job)	**1**	canyons	**1**	real	**4**	world	**1**	information
5	formed (process)	**1**	causation	**1**	reasoning	**6**	formation (rock unit)	**1**	interpret
5	land	**1**	changed	**1**	resources	**3**	formed (process)	**1**	investigate
5	natural	**1**	changing	**1**	rivers	**3**	observe	**1**	keep
5	research	**1**	collect	**1**	safe	**3**	problem (solve)	**1**	lab
4	discover	**1**	construction	**1**	science	**3**	research	**1**	landform
4	explore	**1**	define	**1**	site	**3**	solve	**1**	laws
4	history	**1**	faults	**1**	situation	**3**	understand	**1**	layers (rocks)
4	learn	**1**	field	**1**	society	**2**	discover	**1**	learn
3	features	**1**	formulate	**1**	soil	**2**	environment	**1**	life
3	find	**1**	geography	**1**	specialize	**2**	function	**1**	look
3	form	**1**	ground	**1**	structure	**2**	oil	**1**	make
3	function(s)	**1**	hands-on	**1**	surface	**2**	outside	**1**	movements
3	future	**1**	hike	**1**	survey	**2**	resources	**1**	natural
3	geology	**1**	hypothesis	**1**	tectonic	**2**	shape (process)	**1**	new
3	landforms	**1**	infer	**1**	test	**2**	travel	**1**	people
3	made	**1**	information	**1**	things	**2**	work	**1**	physical
2	affects	**1**	investigate	**1**	travel	**1**	affects	**1**	protect
2	analyze	**1**	issues	**1**	understanding	**1**	age	**1**	safe
2	answer	**1**	knows	**1**	unknown	**1**	analyze	**1**	see
2	apply	**1**	landscapes	**1**	use	**1**	area	**1**	sponsored
2	building	**1**	location	**1**	volcanoes	**1**	better	**1**	structure
2	developed (process)	**1**	man	**1**	water	**1**	characteristics	**1**	structures
2	gas	**1**	meaning	**1**	wonders	**1**	collect	**1**	theory
2	life	**1**	minerals	**1**	workings	**1**	creation	**1**	track
2	oil	**1**	mountains			**1**	drilling	**1**	use
2	outside	**1**	nature			**1**	earthquakes	**1**	volcanoes
2	past	**1**	outdoors			**1**	environments	**1**	works
2	theory	**1**	petroleum			**1**	feature		

Table 2

What a scientist does

Pre-Trip Survey						Post-Trip Survey			
16	discover	**1**	acknowledge	**1**	make	**12**	discover	**1**	concepts
12	study	**1**	animals	**1**	matters	**12**	study	**1**	conduct
17	solve (problems)	**1**	apply	**1**	mystery	**16**	solve (problems)	**1**	draw
9	research	**1**	approach	**1**	objects	**8**	research	**1**	experience
9	world	**1**	blame	**1**	observe	**8**	world	**1**	experiments
8	experiment	**1**	challenge	**1**	opportunity	**6**	earth	**1**	explore
6	learn	**1**	chemistry	**1**	organisms	**6**	understand	**1**	facilitate
6	test	**1**	concepts	**1**	outdoors	**5**	experiment	**1**	hands-on
6	works	**1**	conclusion	**1**	past	**5**	help	**1**	hard
5	earth	**1**	construction	**1**	people	**4**	environment	**1**	history
5	explore	**1**	data	**1**	perform	**4**	explain	**1**	identify
4	find	**1**	dedicate	**1**	produce	**4**	learn	**1**	inferences
4	problems	**1**	environment	**1**	prove	**4**	unknown	**1**	knowledge
4	question	**1**	equations	**1**	reflect	**3**	observe	**1**	laws
4	theory	**1**	evaluate	**1**	repeat	**3**	people	**1**	learning
3	analyze	**1**	experience	**1**	save	**3**	theory	**1**	lives
3	answers	**1**	explain	**1**	sees	**2**	analyze	**1**	never
3	conduct	**1**	explanation	**1**	share	**2**	apply	**1**	observations
3	help	**1**	figure	**1**	society	**2**	data	**1**	occurrences
3	improve	**1**	future	**1**	specialize	**2**	figure	**1**	place
3	lives	**1**	gas	**1**	studies	**2**	improve	**1**	processes
3	natural	**1**	god	**1**	teach	**2**	information	**1**	prove
3	nature	**1**	hands-on	**1**	technology	**2**	investigate	**1**	question
3	understand	**1**	health	**1**	tendencies	**2**	natural	**1**	questions
3	work	**1**	hypothesize	**1**	tests	**2**	nature	**1**	rocks
2	answer	**1**	identify	**1**	theories	**2**	process	**1**	save
2	better	**1**	indoors	**1**	thinking	**2**	reasoning	**1**	solutions
2	create	**1**	inhabitants	**1**	universe	**2**	test	**1**	stop
2	develop	**1**	insight	**1**	unravel	**2**	time	**1**	sustainable
2	hypothesis	**1**	interact			**1**	acknowledge	**1**	topic
2	ideas	**1**	knowledge			**1**	affect	**1**	trial
2	laws	**1**	lab			**1**	ask	**1**	uncover
2	phenomenon	**1**	life			**1**	behind	**1**	understanding
2	questions	**1**	living			**1**	better	**1**	use
2	science	**1**	logic			**1**	break	**1**	utilize
2	unknown	**1**	logical			**1**	build	**1**	work
						1	comprehend		

Supplemental Table X